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United States Department of Agriculture
Agricultural Research Service
Soil and Water Conservation Research Division
Corn Belt Branch

NORTH APPALACHIAN EXPERIMENTAL WATERSHED

COSHOCTON, OHIO

ANNUAL REPORT FOR THE YEAR 1967

In cooperation with the Ohio Agricultural Research and
Development Center
Wooster, Ohio

Prepared by the Station Staff
(List on reverse side)

March 1, 1968

PERSONNEL

L. L. Harrold, Officer-in-Charge
C. R. Amerman, Research Hydraulic Engineer
J. L. McGuinness, Research Statistician
J. B. Urban, Geologist (Ground Water)
W. M. Edwards, Soil Scientist (Physics)

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W. W. Bentz, Hydraulic Engineering Technician
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B. M. Gamble, Clerk-Typist

K. E. White, Operations and Maintenance Leader
R. H. Cunningham, Automotive Mechanic
J. A. Kissner, Maintenance Repairman (OARDC)

C. I. Olinger, Agricultural Research Technician
C. R. Huprich, Farm Equipment Operator
E. W. Burrier, Farm Equipment Operator

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INTRODUCTION

A. Summary of climate

Precipitation for the year totaled 34.09 inches (table 1) and was 3 inches below normal. This is the third successive year and the seventh out of the last eight years when precipitation was below normal. Starting in February 1967, the precipitation alternated from below to above average in each month. June was the driest ever at the station with only 0.74 inch of rain while July with 6.60 inches was well above normal. Intensities were generally low, a 10-minute intensity of 4.50 inches per hour on July 27 being about the peak.

March runoff from the complex watersheds was about 36 percent of the annual total. That for the 3-month period March - May was 71 percent of the total. March values were the fourth largest in the 30 years of record. August values were the eighth least of record. There were no high runoff rates on the small watersheds - a departure from the expected.

Table 1.-Precipitation and runoff summary, 1967

Month	Precipitation		Annual runoff					
	Normal	1967	Corn 1.4 Ac. (113)	Pasture 2.7 Ac. (135)	Woods 2.2 Ac. (131)	Mixed cover 79 Ac. (166)	Mixed cover 303 Ac. (196)	Mixed cover 4580 Ac. (97)
	In.	In.	In.	In.	In.	In.	In.	In.
Jan.	2.83	0.91	0	0	0	0.08	0.19	0.15
Feb.	2.36	1.43	0	0	0	.65	.78	.55
Mar.	3.44	4.64	.35	0	0.	3.99	5.23	3.52
Apr.	3.57	3.03	0	0	0	1.00	1.76	1.17
May	3.85	4.92	T	0	0	2.16	2.75	2.00
June	4.39	.74	.02	0	0	.06	.19	.13
July	4.41	6.60	.71	0	0	.22	.38	.25
Aug.	2.93	1.00	0	0	0	.03	.09	.06
Sept.	2.59	3.37	.04	0	.02	.05	.12	.06
Oct.	2.16	1.59	0	0	T	.04	.11	.07
Nov.	2.41	3.14	.09	0	0	.22	.43	.37
Dec.	2.22	2.72	.03	0	T	1.30	1.52	1.13
Year	37.16	34.09	1.24	0	.02	9.80	13.55	9.46

Soil moisture accretion reached its peak around May 11. Depletion of soil moisture continued until September 26. Total of water utilized in the 0- to 96-inch profile under alfalfa for this period was 25.67 inches of which precipitation supplied approximately 52% and the remainder was extracted from the soil. By the year's end, soil moisture had recovered 7.64 inches above the September low point, and was 4.12 inches above the level on January 1.

Aquifer recharge, in general showed greater replenishment and an increase in storage over 1966. Precipitation during the months of February, March, April and May reversed a short term depletion trend to account for above-average recharge to the principal aquifers. Springflows reflected the trend by contributing greater discharge to watershed streams. Aquifer storage depleted from May 17 to October 31. Most springs flowed throughout the year, unlike 1966. Water levels in the index wells (W-102 and W-110) were at normal or above throughout the year. At the end of the year water levels were above normal in all recording wells.

The average annual temperature for 1967 was 49.6°F, which is 0.6° below the normal mean (table 2). January was the warmest January since 1953 and June the warmest June since 1949. May was the coldest May since records began in 1938 and November the coldest November since 1951. The highest temperature reading was 90° reached in June and the lowest was -3°F. in February.

Table 2.-Monthly air temperature, 1967 (°F)

Month	Maximum	Minimum	Mean	Normal mean	Number of days mean temperature was below freezing
Jan.	66	4	32.5	27.3	18
Feb.	60	-3	25.3	29.1	24
Mar.	78	8	39.9	37.2	8
Apr.	79	23	51.1	49.0	-
May	87	35	54.4	59.4	-
June	90	52	72.2	68.5	-
July	86	52	70.4	72.4	-
Aug.	85	49	68.0	71.2	-
Sept.	82	40	60.2	64.2	-
Oct.	80	27	52.0	53.5	-
Nov.	59	15	35.4	40.6	14
Dec.	64	5	33.6	30.0	14
Year	--	--	49.6	50.2	--

Frost free period was from April 12 to October 20, a total of 191 days - - 12 days above the normal of 179. Average for 30 years shows normal frost free period is April 26 to October 22.

The average daily temperature for the growing season, April through September was 1.40 below normal with only the months of April and June being above normal.

Number of days and depths of frost penetration on wheat and meadow watersheds appear in table 3 together with the 1940-1967 values. There were fewer days of frost and the penetration was shallower on the meadow watersheds than on wheat areas. Vegetative cover on the meadow areas protected the soil against rapid and repeated freezing and thawing.

Table 3.-Frost penetration in 1967 compared with 1940-67 period.

Month	Number of days of frost				Maximum frost depth (inches)			
	Wheat		Meadow		Wheat		Meadow	
	1967	Ave[1/]	1967	Ave[1/]	1967	Max[1/]	1967	Max[1/]
Jan.	25	22	24	15	10.5	11.0	5.5	8.0
Feb.	23	19	14	16	6.5	12.0	3.0	9.0
Mar.	6	10	5	5	4.5	10.5	1.0	5.0
Dec.	8	6	8	7	5.5	9.0	2.0	8.0
Total	62	57	51	43	----	----	---	---

1/ For the period 1940-67.

In 1967 the total number of days of frost penetration was above the 28-year average on both the wheat and meadow watersheds. In January the maximum depth of frost penetration was close to the 28-year record due to lack of snow cover and below normal temperatures. Frost had no effect on runoff in 1967 as there was no significant rain or snowmelt during frost periods.

Data on the depth of snow are given in table 4 together with the 1940-67 averages. Snowfall was considerably above normal for the months of February and March. Total snowfall in 1967 (32.0 inches) was approximately 33% above the average of 24.2 inches. Total days of snow cover was about 67% of normal. A lack of protective snow cover accounted for a longer period of days of frost penetration.

The total snowfall in March was the largest monthly March total and the 8" snowfall on March 8 was the largest daily total for any March on record.

Table 4.-Snowfall in 1967 compared with 1940-67 averages.

Month	Total inches snowfall		Total days of snow cover	
	1967	Average	1967	Average
January	1.0	7.3	5	12
February	12.0	7.1	9	11
March	13.0	3.6	4	6
December	6.0	6.2	8	10
Total	32.0	24.2	26	39

B. Crops

Although total precipitation for the year was 3.28 inches less than the normal of 37.25 inches and that for the May-September growing season 1.66 inches less than the normal of 18.21 inches, crop yields were normal or above. Corn yields averaged 124 bushels per acre on conservation watersheds and 100 on poor practices. Wheat yield on the former averaged 36.1 bushels per acre and on the latter, 23.7. Maximum hay crop was 4.57 tons per acre - - 3.60 in the first cutting and 0.97 in the second. First year meadow hay yield for poor-practice meadow watersheds was 1.68 tons per acre in the first cutting and 0.66 for the second. Second growth on poor-practice second-year meadow was not worth cutting.

C. Changes in personnel

Mr. Dan E. Hall, Hydraulic Engineering Technician retired on January 20, 1967.

Mr. James E. Kissner was employed by OARDC on 6/19/67, replacing E. P. Bowman who left the station on 6/15/67 to engage in other work.

Dr. William M. Edwards, was employed as Soil Scientist (Physics) on 1/1/67, replacing Mr. F. R. Dreibelbis who retired 7/1/64.

Mr. C. R. Amerman, Hydraulic Engineer, was transferred to ARS-SWC, Madison, Wisconsin on November 6, 1967.

The services of three high school girls were obtained through the Neighborhood Youth Corps program during the summer months. They contributed materially to data keypunching, laboratory, and administrative office functions.

Six high school and college students were employed as summer help on the farm and in field, laboratory, and office research programs.

D. Participation in workshops, conferences, and professional societies.

The professional staff participated in numerous events as follows:

1. C. R. Amerman

August 13-Sept. 1.	Univ. of Maryland. Participated in Linear Systems Approach to Watershed Hydrology - short courses. Assisted in instruction.
October 2-6	Berkeley Springs, W. Virginia Division Conference.

2. W. M. Edwards

March 19-20	ARS Annual Pesticide Meeting in Madison, Wisconsin.
June 22-23	ASA. , N. C. Branch Summer Meeting. Participated in Tillage and Crust development Session, Wooster, Ohio
November 6-10	ASA Annual Meeting in Washington, D. C.
December 1	Ohio Soil and Water Tech. Comm. Meeting. Presented "Coshocton Pollution Studies", at Ohio State University, Columbus, Ohio.

3. L. L. Harrold

January 16-17	SCSA All-Ohio Chapter, Columbus, Ohio
17	Ohio Federation SWCD
February 5-8	NACD, Cincinnati, Ohio
14-15	Pollution research, Coshocton, Ohio
March 20	OARDC Agricultural Engineering, Wooster Ohio
27	NC-66, Minneapolis, Minn.
September 20 to October 4	IASH Meeting, Bern, Switzerland
October 18-20	ASCE, New York City
November 13-16	Corn Belt Branch Senior Staff and review of Illinois research program, Urbana, Illinois.
17	OARDC Committee on Water Resources, Columbus, Ohio.

December 4-5	Pollution Research, Beltsville, Maryland.
11-12	ASAE Conference on Tillage, Detroit, Michigan.
13-14	ASAE Winter Meeting, Detroit, Michigan.

4. <u>J. L. McGuinness</u>

April 17-20	American Geophysical Union Annual Meeting, Washington, D. C.

5. <u>J. B. Urban</u>

June 18-30	Flow through porous media with applications to groundwater hydrology, M.I.T. Boston, Massachusetts.

E. <u>Special consultation</u>

The professional staff participated in special and beneficial consultation as follows:

Jan. 13-14	Interflow studies, Madison, Wisconsin
18-20	Research Program, Columbia, Missouri
March 21-22	Consultation at station with Drs. England, Onstad and Jamieson of USHL, Beltsville and station staff on possibility of using our watershed No. 94 for model studies.
May 8-9	Flow of water through porous media, Prof. Bear, M.I.T. Cambridge, Massachusetts.
June - July	J. B. Urban was consultant on thesis problem of B. Caswell, PhD candidate, O.S.U.
July 12	Urban erosion, Independence, Ohio
August 4	Graduate program in evapotranspiration research at West Virginia, University.
June-Aug.	Research Consultant, Soil & Water Conservation, Turkey, L. L. Harrold.
Sept. 1-5	PL 480 consultant, Poland, L. L. Harrold.
6-13	Hydrologic research, Finland, L. L. Harrold.
14-16	Hydrologic research, Denmark, L. L. Harrold.
17-19	Hydrologic research, Germany, L. L. Harrold.

November 20 Strip Mining research, Ohio Power Company, Coshocton, Ohio

21 OSU, Civil Engineering graduate program in watershed models, Coshocton, Ohio

F. Woodlot management.

Rate of tree growth has been decreasing materially for several years in our 29-year old pine plantations. Also in some areas, the stand was so dense, there were no volunteer hardwoods. In order to alleviate stagnation and provide openings in the canopy to encourage natural seeding of hardwoods, a thinning program was started in 1967.

In watershed 172, approximately 70% of the plantation area received a selective thinning. In areas where there was an influx of hardwood seedlings most pines were cut, leaving only white pine (P. strobus) and pole-size hardwoods.

Trees were felled and left.

No satisfactory local market was available for pine pulp wood, so no attempt was made to sell the products as man power, equipment, and transportation costs would be greater than any value received from these products.

Soil Conservation Service has expressed great interest in this program as it is a good demonstration of what needs to be done on SCD farm pine plantations. Norris Quam (SCS forester in Ohio) is investigating markets for the cuttings. His examination of the stumps showed very little volume increase in the past 10 years. He plans to make growth studies and changes in basal area following cutting.

Continuous water yield data are being collected and when thinning is completed, basal area will be recorded. Growth rates will be determined about 5 years later.

G. Frost penetrometer

A gage for observing depth of frozen ground, patterned after one seen at the Danish Hydrotechnical Laboratory, Copenhagen, was made and installed in the field. The gage can be lifted out of an access tube and the depth of frost is observed as the portion of the column of methylene blue that is colorless (frozen).

REPORTS BY INDIVIDUAL EXPERIMENTS

A. CRIS WORK UNIT: SWC W3-cCos-1

Research Outline: Studies of precipitation characteristics influencing runoff from agricultural watersheds, Ohio-1.

B. LOCATION: Coshocton, Ohio

C. PERSONNEL: J. L. McGuimness and L. L. Harrold; cooperators: Grant Vaughan, U.S. Weather Bureau, Akron-Canton Airport; Ohio Agricultural Research and Development Center.

D. DATE OF INITIATION AND EXPECTED DURATION: 1937 - continuing.

E. OBJECTIVE: Development of methods of characterizing watershed precipitation.

F. NEED FOR STUDY: Rainfall is the most important factor in predictions of streamflow from ungaged watersheds in the Corn Belt area.

G. DESIGN OF EXPERIMENT AND PROCEDURES TO BE FOLLOWED: A network of 20 recording rain gages is maintained on the Station and Little Mill Creek areas to provide knowledge of the input to watershed areas. Measurements of wind speed and direction, air and soil temperatures, pan evaporation, and other climatic measurements are made at an Index Plot as an aid in interpreting their influence on the relationship of land physiography on precipitation and other hydrologic data collected at the Station. Precipitation data are analyzed to develop methods of computing average watershed precipitation, depth-area-duration curves, storm distributions and frequency distributions of rainfall amounts and intensities. The data are also input values in water budgeting and storm rainfall vs. runoff studies.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Variability of rainfall on a small area related to physiography.

The annual report for 1966 described precipitation measurements on a pasture area of about 30 acres and figure 1 of that report is reproduced here as figure 1.1 to show the location of the rain gages, the topography, and the precipitation pattern. Readings were continued through April, 1967, without appreciable change in the pattern of figure 1.1.

In addition to elevation, eight other characteristics of the rain gage sites were listed in an attempt to explain the rainfall pattern of figure 1.1. Data for selected gages are given in table 1.1. The ground slope at each gage was

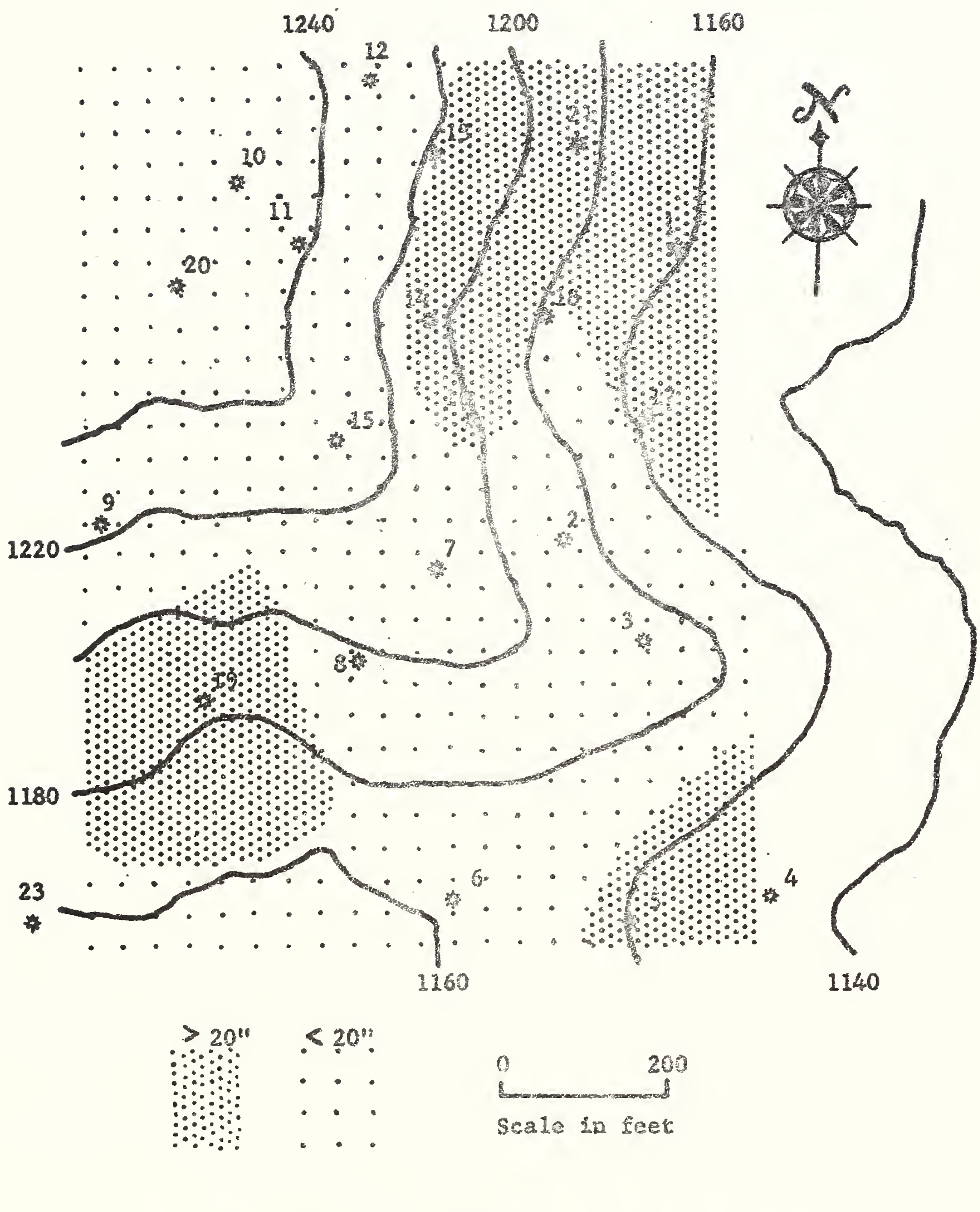


Fig. 1.1.-Rain gage network, topography, and 1966 precipitation catch on Watershed 157.

Table 1.1.--Gage site descriptions for selected gages

Site parameters	Gage number			
	10	8	16	4
Elevation, ft. MSL	1248	1198	1200	1144
Slope, %	4	12	21	8
Aspect	NE	SW	E	E
Position	1.00	.86	.67	.19
Shelter, ft.	- 5	- 5	5	22
Ridge distance, ft.	155	130	165	270
Ridge direction	NE	SW	NE	S
Exposure, radians:				
NE	.77	.24	1.13	.88
SE	1.57	1.57	1.57	.10
SW	1.04	1.15	0	0
NW	1.00	0	0	0
Rise, ft.:				
NE	17	32	59	21
SE	0	0	0	25
SW	57	41	50	51
NW	13	61	85	69

measured along a 100-foot transect normal to the contours and centered at the gage. The aspect at each site was recorded to eight directions. Position on slope was determined by drawing the shortest possible line from the nearest ridge to valley through the gage, and computing gage elevation minus valley elevation divided by the difference in ridge and valley elevations; a fully exposed gage on a ridge would have a rating of 1.0. Shelter was measured by determining the difference between the site elevation and the elevation of a point above the gage on the shortest line connecting opposite ridges. Distance and quadrant direction of the gage site from the nearest ridge were determined. In each of the four directional quadrants (NE,SE, SW, NW), exposure was determined as the angle in radians without obstructions higher than the gage within an arc of 660 feet radius and rise was the elevation difference between the gage and the highest point within the above arc.

The correlation coefficients between the nine "independent" topographic variables and precipitation catch for all storm directions is given in table 1.2. It is obvious that the "independent" variables are not truly independent, the exposure factor, for instance, being significantly correlated with six of the other topographic factors as well as with precipitation. Thus, a straight-forward regression analysis approach is ruled out.

Table 1.3 shows the correlations between the topographic factors and precipitation when the storms are separated on the basis of the direction from which they came. Many inconsistencies are apparent.

Table 1.2 -- Correlation coefficient matrix for all storm directions

	Elevation	Slope	Aspect	Position	Shelter	Ridge Dist.	Ridge Direct.	Exposure	Rise	Precipitation
Elevation	1.00	-0.11	-0.09	0.49	-0.66	-0.63	-0.44	0.66	-0.34	-0.55
Slope		1.00	.16	- .30	.16	.14	.05	- .29	.20	.41
Aspect			1.00	.05	- .28	- .12	.18	- .13	.30	.03
Position				1.00	- .84	- .76	- .38	.76	- .39	- .65
Shelter					1.00	.84	.45	- .72	.31	.48
R. Dist.						1.00	.42	- .74	.38	.44
R. Direct.							1.00	- .46	- .04	.20
Exposure								1.00	- .61	- .50
Rise									1.00	.30
Precip.										1.00

Values greater than 0.413 and 0.526 are statistically significant at the 5% and 1% levels, respectively.

Table 1.3.-Simple correlation coefficients of precipitation with topographic factors by storm direction.

Precipitation and:	NE storms	SE storms	SW storms	NW storms	All storms
Elevation	-0.09	-0.49	-0.22	-0.30	-0.55
Slope	- .07	- .44	.45	.39	.41
Aspect	.54	.35	- .38	.56	.03
Position	.03	- .01	- .53	- .27	- .65
Shelter	- .16	.15	.39	.09	.48
Ridge Dist.	- .21	.13	.32	.26	.44
R. Direct.	.27	.30	- .03	.17	.20
Exposure	- .43	- .50	- .80	- .31	- .50
Rise	.08	.47	.05	.61	.30

Values greater than 0.413 and 0.526 are statistically significant at the 5% and 1% levels, respectively.

For instance, ground slope and precipitation are negatively correlated in SE storms (r= -0.44) but positively correlated in SW storms (r= 0.45). Exposure is the most consistent topographic factor being negatively correlated with precipitation in every case and significantly so in every case but one.

Analysis of the topographic and precipitation factors by multiple regression analysis is precluded by the strong intercorrelations between the "independent" variables, table 1.2. The more sophisticated multivariate analyses have been advocated in such cases so principal component analyses were made on these data. The results for all storms are given in table 1.4.

Table 1.4.--Eigenvalues and eigenvectors for topographic factors for all storm directions.

	Eigenvectors								
	1	2	3	4	5	6	7	8	9
Elevation	-0.36	-0.00	-0.23	-0.16	-0.82	-0.12	-0.20	-0.06	-0.24
Slope	.14	- .37	- .36	- .79	.24	- .12	- .11	.06	- .00
Aspect	.01	- .71	.42	.05	- .13	.49	- .06	.06	- .23
Position	- .41	- .07	.16	.13	.42	- .41	- .44	- .10	- .48
Shelter	.43	.28	- .08	- .02	- .02	.09	.13	.41	- .73
Ridge Dist.	.42	.17	- .05	.08	- .06	.24	- .83	- .10	.15
R. Direct.	.26	.07	.70	- .28	- .23	- .49	- .04	.19	.15
Exposure	- .43	.15	.03	- .08	.09	.23	- .19	.79	.24
Rise	.25	- .46	- .34	.48	- .10	- .46	- .05	.37	.14
Eigenvalues	4.44	1.43	1.06	.88	.47	.31	.20	.16	.06

The eigenvalues on the bottom line of the table are standardized variances of each component. The first component accounts for 49% of the total variation (4.44/9), the first two components for 65% (5.87/9), etc.

The eigenvectors may be viewed as regression coefficients between the original topographic factors and the various components. Component 1 is made up of three factors relating to exposure of the gage to the wind (elevation, position, and exposure), plus two factors relating to sheltering of the gage from the winds (shelter and ridge distance). In this component, ridge direction and rise do not seem to be too important while slope and aspect have only negligble influence.

The second component contains elements of slope, aspect and rise. Component 3 features slope and rise along with aspect and ridge direction while component 4 is made up of slope and rise. The task of explaining these components in terms of physical characteristics is formidable.

Arlin Hicks of the Chickasha Station very kindly ran a varimax rotation of the factor matrix. This analysis showed that the highest loaded factor on the dependent variable is unique. This is interpreted as meaning that not very much of the variance of precipitation can be explained by the independent variables included in the analysis. This analysis was made using five eigenvalues. Had only four been used, the variables slope and shelter would have been suggested for use in regression analysis.

Since the multivariate techniques do not seem to be of much help in this case, we can try to rationalize a prediction model. From table 1.3, exposure seems to be the one factor most consistently correlated with precipitation and it also shows up as one of the important factors in component 1 (table 1.4). Since it is well correlated with some of the other topographic factors (table 1.2), we can use exposure as an index of the lack of protection of the gage from the wind, if we drop elevation, position, shelter and ridge distance from consideration.

Slope and aspect are not significantly correlated with each other or with exposure (table 1.2) but seem to be related to precipitation amount (table 1.3) in most cases. Both have some importance in component 2 (table 1.4) and are therefore included in the proposed analysis with exposure.

This leaves ridge direction and rise to be considered. Ridge direction and rise are correlated with exposure (table 1.2) but not too well related to precipitation (table 1.3). Ridge direction has some relation to component 3 and rise is related to component 2 but their correlations with exposure are such as to suggest excluding them from the proposed analysis.

In addition to the above factors, a separate analysis was made of the influence of slope and shelter on precipitation since the factor analysis indicated that these factors might have some importance.

The results of analysis of the regression of precipitation on various combinations of independent variables are given in table 1.5.

Table 1.5.--Simple and multiple correlation coefficients of precipitation on various combinations of topographic factors.

Factors	NE storms	SE storms	SW storms	NW storms	All storms
Exposure	-0.43*	-0.50*	-0.80**	-0.31	-0.50*
Exposure + Slope	.44	.60*	.80**	.41	.57*
Exposure + Aspect	.58*	.64**	.82**	.57*	.50
Exposure + Slope + Aspect	.60*	.75**	.83**	.64*	.57*
Shelter + Slope	.18	.50	.56*	.39	.58*

*Statistically significant at the 5% level.
** Statistically significant at the 1% level.

The land slope at the gage site does not seem to have as much influence as aspect (compare lines 1 and 2 vs. lines 1 and 3). Thus a rational prediction model involving exposure and aspect would seem to be indicated. However, the R-values on the third line of table 1.5 show that this model is not really successful in explaining the variability of the precipitation patterns of figure 1.1. The model suggested by the multivariate analyses (line 5) must also be considered a failure.

If there is any real relationship between topographic parameters and precipitation catch, these analyses have certainly not demonstrated it. Unfortunately, the data are too scanty to permit subdividing into months or days. When the data processing program for our recording rain gage data is completed, some further analyses along the above line may be attempted.

Comparison of Recording and Fischer & Porter Punch Rain Gage.

A Fischer & Porter Series A1 punch rain gage with data set was installed on the Index Plot early in 1967 as part of a flood forecasting network operated by the Weather Bureau office in Pittsburgh, Penna. The F&P gage is only about 20 feet from a Belfort 5-780 weighing type rain gage.

Routine comparison of monthly totals from the two gages during the May-September period showed that the F&P gage was catching over 10 percent more precipitation than the recording gage. The percentage difference was quite stable over the different months. The more streamlined shape of the F&P gage might tend to increase its catch over that of a similarly exposed recording gage but the higher placement of its orifice (66 inches compared with 48 inches for the recording gage) would tend to make it catch less.

Both gages were inspected in late September. The orifice of the recording gage was found to be very slightly elliptical in shape instead of perfectly round. This distortion is due to the locking seam inside the receiver. Very careful measurements were made and it was calculated that the "deformed" gage orifice might increase the catch about 0.5 per cent. This was so insignificant that no corrective action was taken. Both gages were calibrated and put in first class operating condition.

It is planned to study the differences in catch on a storm by storm basis. An anemometer and direction vane are located in the Index Plot which also includes a Fourcade-type directional rain gage. These should provide sufficient information so that the storms can be analyzed by direction. Additional comparisons between F&P and other gage types may be made for other USWB installations whose data are available to Grant Vaughan of the Akron-Canton Airport.

Pan Evaporation:

Measurement of evaporation from a Class A pan has presented some vexing problems. One of these has been the fact that readings are made at 0800 EST on workdays only. Thus, evaporation from 0800 Friday to 0800 Monday is lumped into a single figure leaving only four daily values per week for analysis.

During 1967, a water level instrument was added to the pan installation to provide a continuous trace of pan water levels and pan evaporation was computed on a calendar day basis as well as from the 0800-0800 manual readings. An analysis was made of calendar day totals and the following 0800-0800 values for all days during 1967 when no measurable rain fell. The results are given in figure 1.2.

The correlation coefficient of 0.834 is highly significant for the 60 pairs of readings. The regression equation for estimating calendar day values from the 0800-0800 readings is: C.D. = 0.972 (0800 Read.)-0.006. The slope, 0.972, is not significantly different than 1.0 and the intercept, -0.006, is not significantly different than zero.

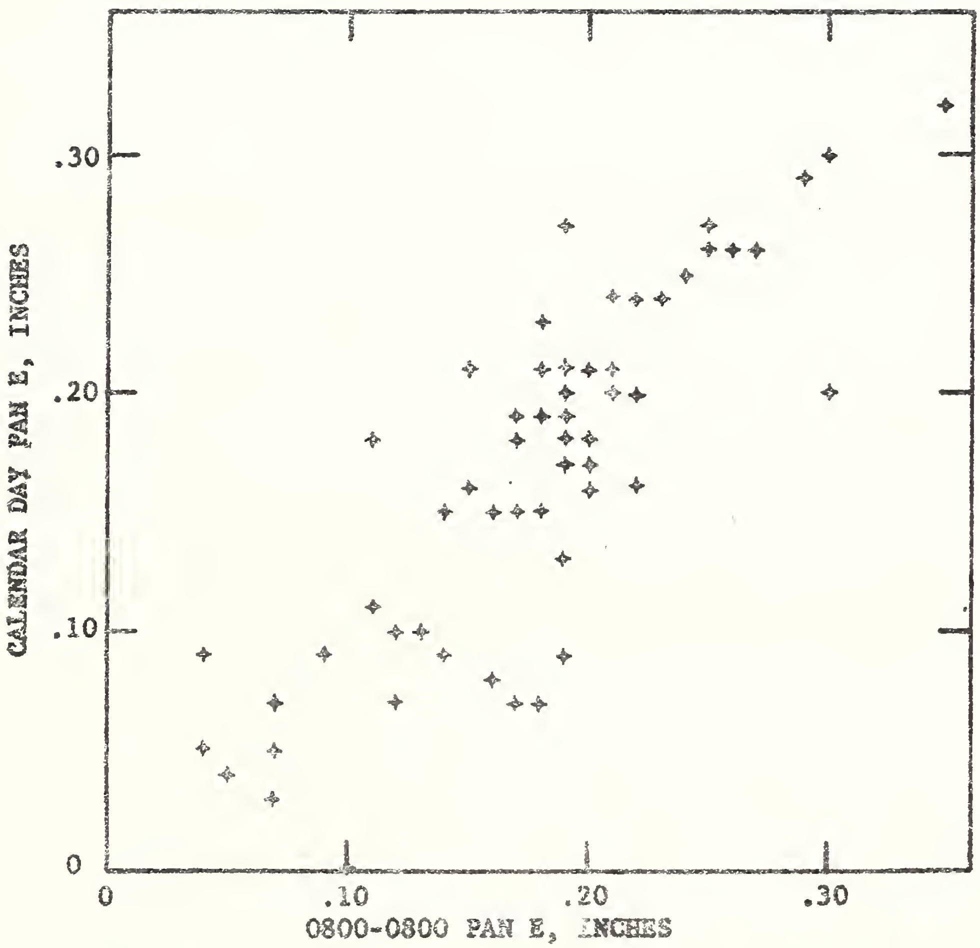


Fig. 1.2--Relation between 24-hour pan evaporation amounts starting at midnight and 0800 hours.

The standard error of estimate for the relationship is 0.085 inch. It is obvious that there is a good deal of scatter present and that predictions of calendar day values from 0800-0800 readings will not be very precise. However, the close agreement between the computed regression line and a one-to-one relationship indicates that very little bias exists in the prediction.

The pen trace of water level in the evaporation pan also afforded an opportunity to check on the amount of water added to the pan by rainfall as compared with the amount caught by a nearby recording rain gage. The data are shown in figure 1.3. It is obvious that the pan is catching less than the gage, the regression equation being: Pan = 0.771 Gage + 0.037, with a correlation coefficient of 0.995.

Some small part of the difference in catch is due to evaporation which occurs from the pan during and between rain showers. The major difference, however, is probably due to splash out of the evaporation pan. The standard practice of adding the rain gage amount as accretion before computing pan evaporation for a rain day is a likely cause of error on those days.

If additional data follow the pattern shown on figure 1.3, perhaps a more realistic method of allowing for rainfall can be devised.

Soil Moisture Simulator:

When we visited the Chickasha Station in the fall of 1966, we saw a device being used as an indicator for timing irrigation. A copy of this device was operated on the Index Plot at Coshocton this past season. It consists of four glass measuring tubes, 3/4 inch in diameter, mounted on a small platform. One horizontal slot is cut in each tube at 4, 3, 2, or 1 inch rainfall capacity so that the four tubes have a total capacity of 10 inches when each is filled to capacity. This is approximately the available water capacity of the top 40 inches of our soils.

The four tubes were filled with water at mid-April when soil moisture was about field capacity. As soil moisture depleted during rainless periods, water in the four tubes also depleted. When rain occurred, both soil moisture and the four tubes were recharged. The four slots in the tubes prevented recharge above the total 10-inch capacity.

When soil moisture is high, the tubes are nearly full and all four tubes are evaporating water to the atmosphere. As depletion occurs, the 1-inch tube dries out and only 3 tubes are evaporating. Unless significant replenishment by rainfall occurs, the 2-inch and then the 3-inch tube dries out as depletion continues leaving only the 4-inch tube evaporating. During this process, the rate of

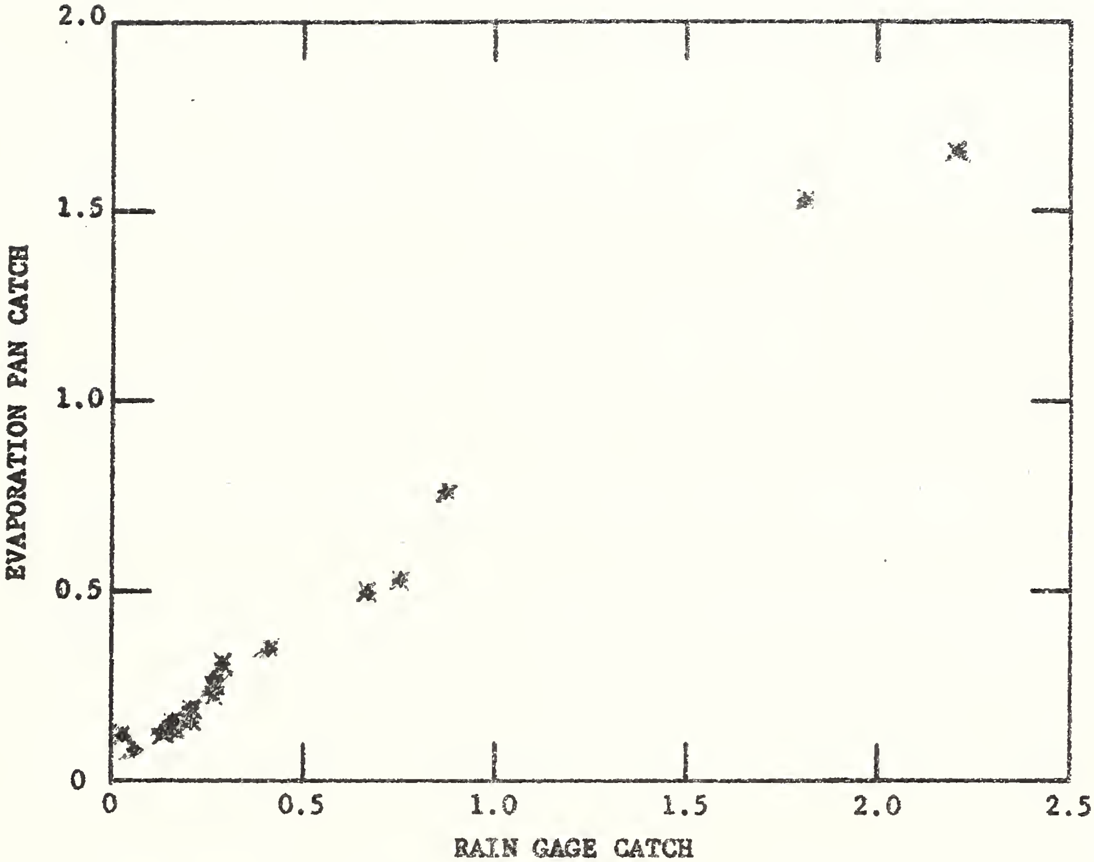


Fig. 1.3--Relation between rain gage catch and amount caught by Class A evaporation pan.

evaporation from the four tubes is a step-like function which hopefully simulates the depletion of soil moisture. The devise was labeled SMS for soil moisture simulator and was operated from April 21 through October 27.

The relationship between the total water held by the SMS at 0800 on Fridays and precipitation minus pan evaporation during the 7-day periods ending at that same time is given in figure 1.4. The regression equation is P-E = 0.245 SMS - 1.438 and the correlation coefficient of 0.848 is highly significant. The SMS does a fair job of integrating these two important climatic factors over weekly periods.

Figure 1.5 shows the relation between the total water in the SMS and that measured under grass cover in three soil depths as of 0800 on Fridays. Correlation coefficients for the 0-7, 0-15, and 0-39 inch depths of soil moisture are 0.880, 0.751, and 0.428 rspectively, all statistically significant, the first two highly so. The three regression equations are:

SM(0-7) = 0.265 SMS + 0.601; standard error = 0.42

SM(0-15) = 0.293 SMS + 2.626; standard error = 0.71

SM(0-39) = 0.238 SMS + 9.353; standard error = 1.40

Polynomial curves were fitted to the three sets of data but did not result in an improvement over the linear relationships shown.

There was not a strong relationship between the SMS readings and evapotranspiration as measured from the permanent grass lysimeter. The correlation coefficient for weekly values was -0.298, not significant. This is somewhat surprising since the SMS was so highly correlated with soil moisture. However, the correlations did weaken as the soil moisture profile depth increased up to 39 inches. In the case of the lysimeter, the ET values can be considered as soil moisture changes from a 96-inch profile.

I. COMMENTS AND INTERPRETATIONS:

Included in Section H.

J. SUMMARY:

Extensive analysis of the effect of nine topographic factors on rainfall catch did not reveal any usable relationships. The topographic parameters included elevation, slope, aspect, position on slope, shelter, ridge distance and direction, exposure and rise. Of these, exposure and aspect seemed to be best related to precipitation catch.

A Fischer and Porter punch gage has been consistently catching about 10 percent more precipitation than a similarly exposed recording rain gage. An investigation into this difference has begun.

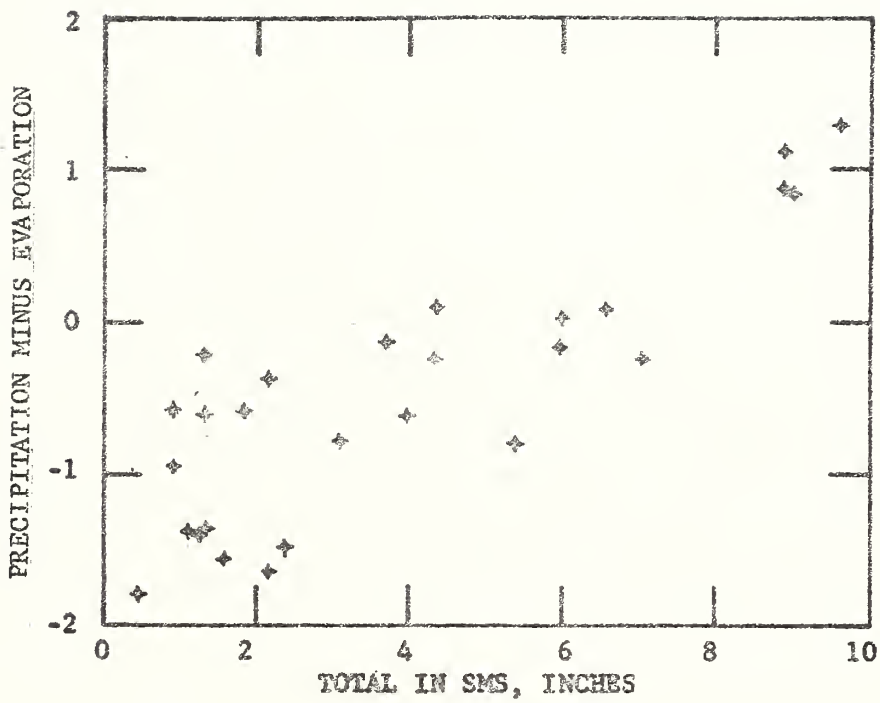


Fig. 1.4 -- Relation between total water in SMS at 0800 on Fridays and precipitation minus pan evaporation for 7-day periods ending at same time.

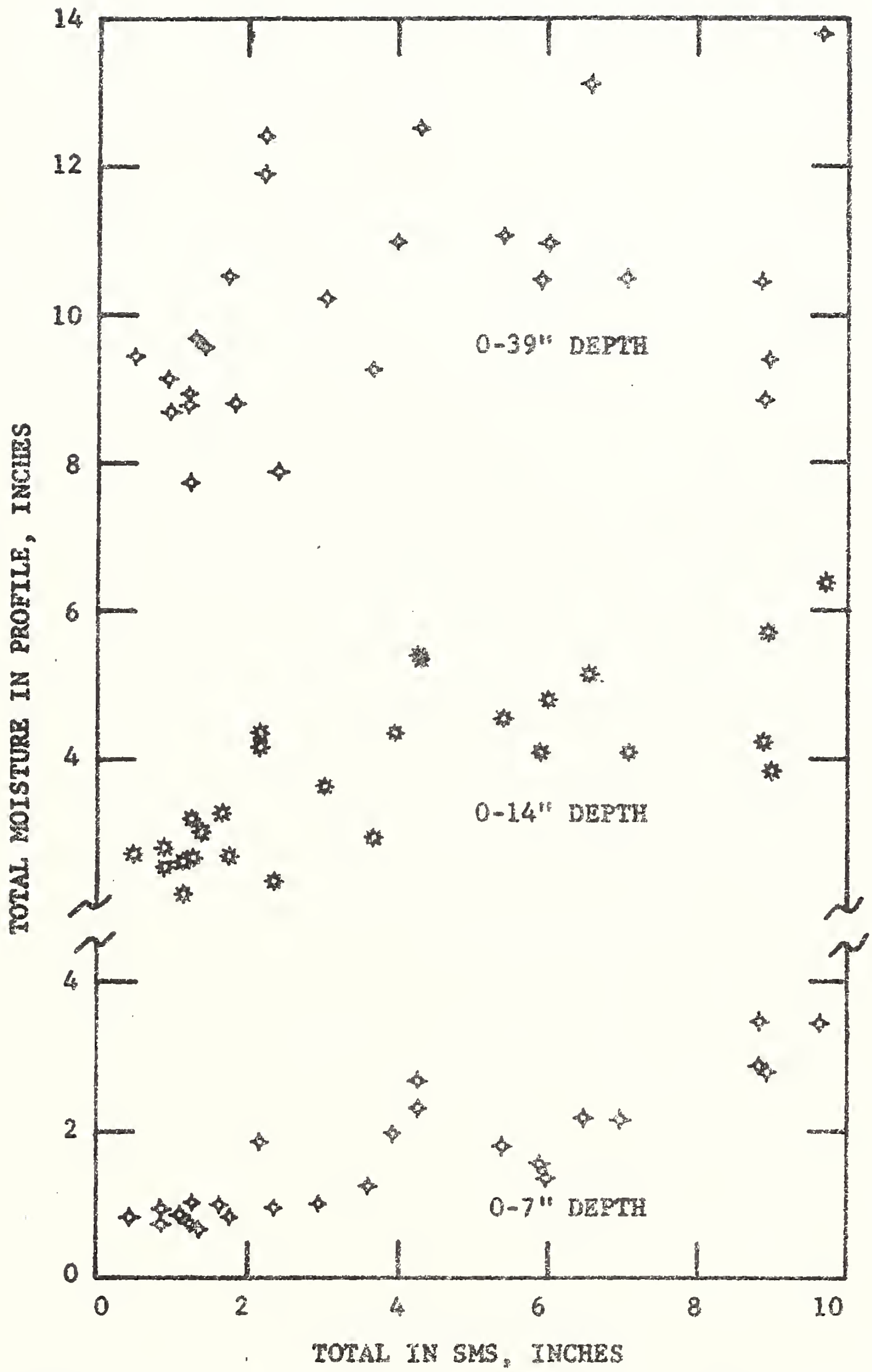


Fig. 1.5.—Relation between total water in SMS at 0800 on Fridays and amount of moisture in profile at same time.

Pan evaporation from 0800 to 0800 was closely related to midnight to midnight values. The pan is inefficient in catching rainfall but the usual practice of adding values of rain gage catch into the pan evaporation calculations makes a likely source of error on days with rain.

A soil moisture simulator (SMS) gage was successfully tested. The SMS readings were well correlated with precipitation minus evaporation values and with soil moisture in the 0-7 and 0-15 inch soil layers. The readings did not correlate too well with soil moisture from the 0-39 inch profile or with lysimeter ET from grass. The device has possibilities as an indicator of irrigation needs for shallow-rooted crops.

A. CRIS WORK UNIT: SWC W3-cCos-2

Research outline: Moisture regimes of agricultural watersheds, Ohio-2.

B. LOCATION: Coshocton, Ohio

C. PERSONNEL: R. E. Youker, W. M. Edwards, L. L. Harrold, J. L. McGuinness; cooperation - Ohio Agricultural Research and Development Center, Wooster, Ohio.

D. DATE OF INITIATION AND EXPECTED DURATION: 1940 - continuing.

E. OBJECTIVES: 1. To maintain a soil moisture inventory on the agricultural watersheds.

2. To evaluate the accretion, depletion, and storage of soil water under various land use and climatic influences as one of the key factors in evaluating the hydrologic performance of agricultural watersheds.

3. To develop methods of estimating soil moisture conditions under various land use and climatic influences.

4. To evaluate zone of frozen soil and characterize type of frost structure as it affects soil moisture storage, runoff, and percolation.

F. NEED FOR STUDY: Soil moisture storage is influenced by cover, soil type, tillage and climate and in turn exerts an influence on evapotranspiration, flood flows, subsurface hydrology, and water yield. Quantitative information on these influences is needed in this area in order to assist in flow systems analysis for watershed engineering and water budgeting programs and in studies in the field of water management.

Depth of frost penetration and characterization of its structure are needed in relating flood-runoff and flow-volume to rainfall and snowmelt on frozen soil and to watershed and climatic conditions.

G. DESIGN OF EXPERIMENT AND PROCEDURE TO BE FOLLOWED: A periodic inventory of soil moisture is maintained on the meteorological index plot and on selected watersheds representing different crops and soils. Inventories are taken soon after storm periods and at regularly scheduled intervals to provide information on recharge and data needed for water budgeting. A continuous measurement of factors affecting the water budget (rainfall, runoff, percolation, and evapotranspiration) is made by recording lysimeters. The inventory furnishes a body of background information which is of use in properly relating the other variables in the hydrologic system.

Access tubes for measuring soil moisture at depth with the neutron probe and electrical resistance fiberglas gypsum blocks for detecting moisture changes in the topsoil are installed in lysimeters and at a number of points in watersheds. Soil moisture readings taken along a downslope transect indicate subsurface water movement downhill. Frequent measurements are taken throughout the profile at several points on the slope following high recharge storms in an attempt to define relocation of soil water.

A series of moisture prediction schedules is developed, based upon the depletion rate observed between consecutive profile measurements. Soil moisture changes under various crop cover, soil type, and depths are measured to provide the basis for estimating depletion.

Records of soil and air temperature, relative humidity, net and solar radiation, wind movement, and pan evaporation, which may be shown to influence soil moisture changes are maintained at the index plot. Hourly and daily rates and values are used in validating theoretical equations which relate climatic and energy factors to soil moisture loss and in interpreting the other hydrologic data collected at the station.

Frost depth and character are determined by picking through the frozen soil and by visual examination. Frozen soil conditions are related to early spring and winter runoff from rain and melting snow.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Soil water inventory (lysimeters)

The weighing monolith lysimeters provided data (table 2.1) on accretion, depletion, and storage of soil water during the growing season of 1967. Monthly values of precipitation and of storage changes are given for the period April through September together with monthly values of the depletion factors (surface runoff, evapotranspiration, and percolation) for each of the three weighing lysimeters.

I. COMMENTS AND INTERPRETATIONS: Precipitation was below normal for April, June, and August, while in May, July, and September, it was above normal. The total precipitation for this entire period was approximately 90% of normal. Total deficits amounted to 8.62, 7.48, and 5.18 inches, on Y101D, Y102C, and Y103A, respectively.

ET on Y101D in May was much less than on Y102C and Y103A due to an alfalfa blight which reduced leaf development, thus reducing its ET. After spraying for the blight, plant development resumed and the rate of ET increased.

Figure 2.1 depicts the accumulative ET on the three lysimeter boxes for the 3-month period June - August. ET on Y102C in June was much less than that on the other two boxes due to its earlier hay-cutting date, which reduced ET rate. Y103A box was clipped six days later and the rate of ET recovery was later thus the small values of ET in July in comparison with those of Y102C and Y101D.

Table 2.1-Monthly summary of the accretion, depletion, and storage of soil water for the growing season, 1967
(Expressed in inches of water)

Month	Lysimeter	Precipitation	Depletion: Evapotranspiration	Depletion: Percolation	Depletion: Runoff	Depletion: Total	Storage: Increase +	Storage: Decrease -
April	Y101D[1/]	3.42	3.21	0.70	0.02	3.93	-	0.51
	Y102C[2/]	3.34	3.67	.82	0	4.49	-	1.15
	Y103A[3/]	3.42	3.42	.49	.02	3.93	-	.51
May	Y101D	5.36	4.71	.91	.09	5.71	-	.35
	Y102C	5.36	5.61	1.31	.01	6.93	-	1.57
	Y103A	5.24	5.29	1.08	.02	6.39	-	1.15
June	Y101D	.81	5.95	.26	.01	6.22	-	5.41
	Y102C	.79	4.80	.17	0	4.97	-	4.18
	Y103A	.80	5.33	.10	0	5.43	-	4.63
July	Y101D	6.79	4.96	.01	.01	4.98	1.81	-
	Y102C	6.60	4.78	.04	.03	4.85	1.75	-
	Y103A	7.08	3.74	.06	.02	3.82	3.26	-
August	Y101D	1.54	5.49	0	0	5.49	-	3.95
	Y102C	1.21	3.93	.02	0	3.95	-	2.74
	Y103A	1.22	3.88	.04	0	3.92	-	2.70
September	Y101D	3.62	3.82	0	.01	3.83	-	.21
	Y102C	3.41	2.97	.01	.02	3.00	.41	-
	Y103A	3.27	2.70	.02	0	2.72	.55	-
Total April to Sept.	Y101D	21.54	28.14	1.88	.14	30.16	-	8.62
	Y102C	20.71	25.76	2.37	.06	28.19	-	7.48
	Y103A	21.03	24.36	1.79	.06	26.21	-	5.18

1/ Muskingum silt loam (sandstone); alfalfa
2/ Muskingum silt loam (shale); meadow
3/ Keene silt loam; meadow

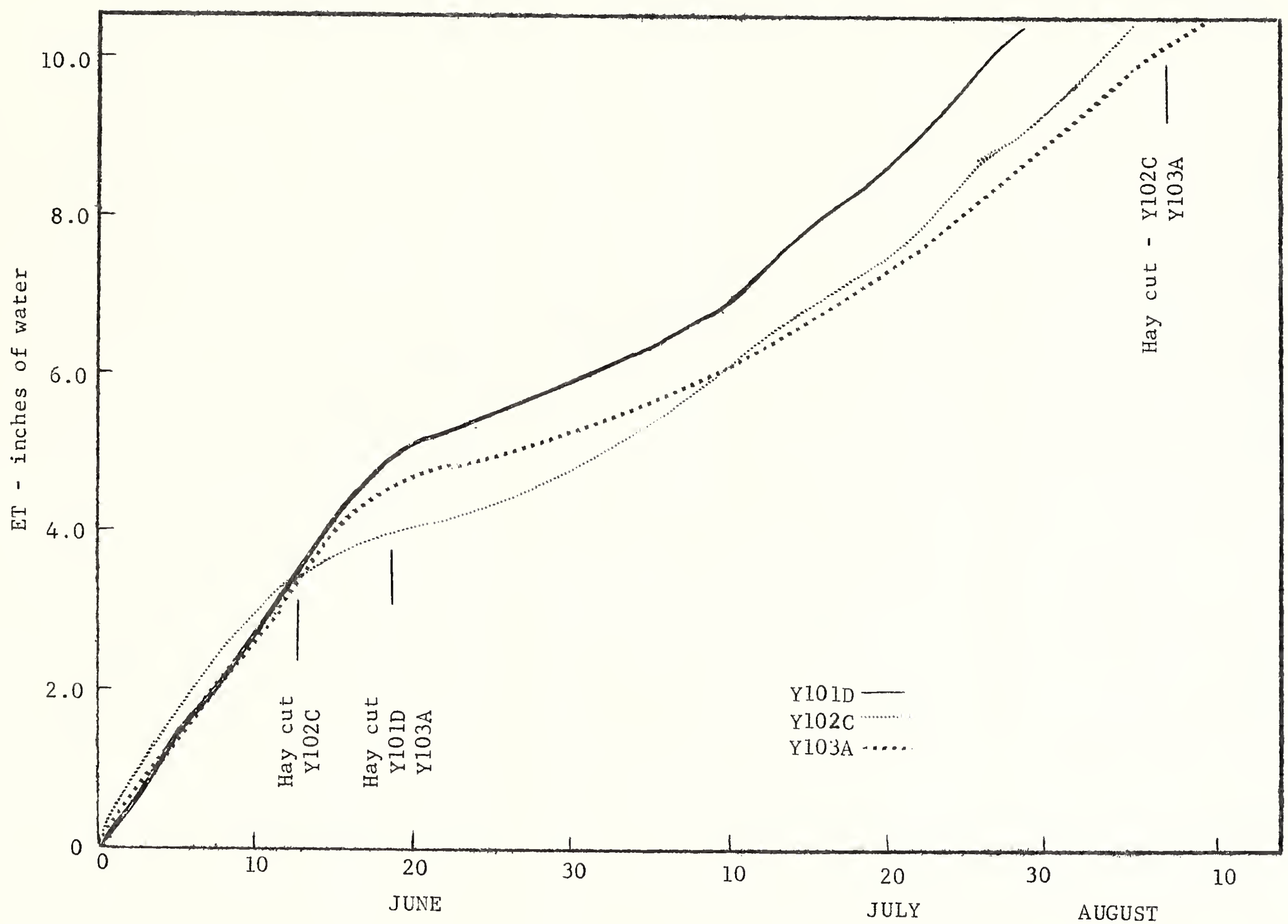
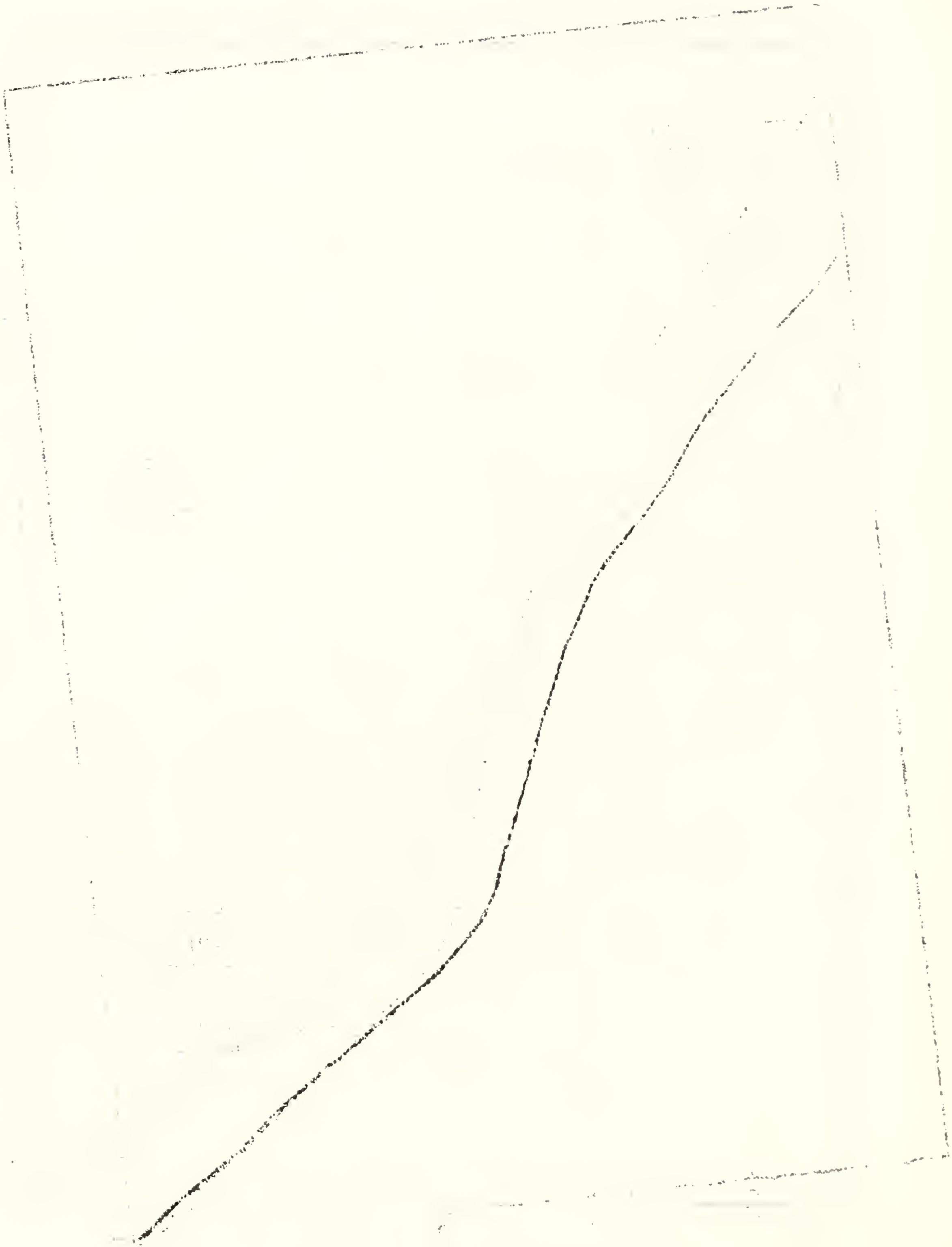


Fig. 2.1 -- Cumulative ET for alfalfa (Y101D) and for meadow (Y102C and Y103A), 1967



The leaf area was much greater on Y101D after the first cutting, thus a higher ET rate for the rest of the growing season. Total depletion was greater under deep rooted alfalfa (Y101D) for the 4-month period June - September.

J. SUMMARY: Lysimeter soil water inventory for 1967 showed greatest depletion under alfalfa (Y101D) with Y102C meadow next and Y103A meadow the least. This is in line with the drainage characteristics of the soils in these three lysimeter boxes -- from well to slowly drained. Although June precipitation was the smallest amount for any June since the inception of the lysimeters, water use during this month was quite high, indicating an adequate supply was available in the soil.

After a hay crop is removed from the boxes, the rate of ET is greatly diminished for several days (Fig. 2.1), until the leaf surface has been reproduced. If the second growth is sparse as it was on Y102C and Y103A, the rate of ET is small.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Summary of accretion and depletion (lysimeters)

Table 2.2 presents a summary of accretion and depletion of soil water for the growing seasons (April through September) for the period 1944-66.

Table 2.2-Average growing season (April-September) summary of accretion and depletion of soil water for the period 1944-66.

Number of years	Lysimeter	Precipitation	Depletion				Water supply from	
			ET	Percolation	Runoff	Total	Soil	Precip.
		In.	In.	In.	In.	In.	%	%
23	Y101D	21.83	26.28	3.96	0.13	30.37	28	72
20	Y102C	22.11	25.00	3.03	.59	28.62	23	77
21	Y103A	22.38	26.74	2.05	.20	28.99	23	77

I. COMMENTS AND INTERPRETATIONS: Lysimeter boxes Y102C and Y103A are in comparable rotation of corn, wheat, meadow and meadow. It is interesting to note that the average percolation value for the slowly-permeable Y103A soil was less than that for the well drained soil of Y102C. That from both rotation boxes was less than from Y101D permanent grass mixture. The percentage of total water use supplied from the soil (23%) was identical in both of the rotation lysimeters - and 5% less than from that of the permanent grass, box (Y101D).

Runoff values are small - representing that from a land slope of only 14-foot length down from the ridge top. As expected, average runoff from the rotation crop areas was the largest. That from Y102C, on 13 percent slope, of 0.59 inch was larger than that from Y103A on 6 percent slope (0.20 inch) -- ratio of almost 3 to 1.

J. SUMMARY: Long term averages show an identical supply of water from the soil for the rotation crops from lysimeters Y102C and Y103A (23%). The percolation averages were least from the slowly permeable Y103A, next was Y102C moderately permeable, and the greatest from the well drained Y101D. Percentage-wise, the precipitation supplied 72-77% of water depletion from the three boxes.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Water budget studies (lysimeters)

Data for 1967 water budget studies on lysimeters are given in table 2.3. The data are divided into two periods: (1) from April 1 (approximate start of growing season) to the first cutting and (2) between first and second cuttings.

I. COMMENTS AND INTERPRETATIONS: The first period (74-80 days) had more rainfall, more percolation, more soil moisture depletion, and a higher average daily ET rate on Y102C and Y103A (but lower on Y101D) than the second period (48-59 days).

For the first period of growth, precipitation supplied 70%, 69%, and 66% of crop water use for Y101D, Y102C, and Y103A, respectively - very little change. For the second period of growth, 76%, 100%, and 144%, in the same order, with Y103A showing an increae in soil moisture. Quite possibly the increase in soil moisture on Y103A of over 2 inches was due to the lesser ET from a poor stand of vegetation remaining after the first cutting. The yield from the first cutting on Y101D was low due to blight damage of the crop.

Table 2.3.-Water budget studies on lysimeters, crop season, 1967

Lysimeter	Y101D		Y102C		Y103A	
Vegetation	Alfalfa		Meadow		Meadow	
Soil type	Muskingum silt loam over sandstone		Muskingum silt loam over shale		Keene silt loam	
Period	April 1 to June 19	June 20 to August 18	April 1 to June 13	June 14 to August 7	April 1 to June 19	June 20 to August 7
	Inches	Inches	Inches	Inches	Inches	Inches
Rainfall	9.04	7.62	8.88	7.41	8.93	7.82
Percolation	1.86	.03	2.23	.12	1.69	.11
Surface runoff	.11	.02	.01	.03	.04	.02
Soil moisture (0-96" depth)	-5.91	-2.40	-6.18	- .16	-6.30	+2.27
Evapotranspiration	12.98	9.97	12.82	7.42	13.50	5.42
Average daily ET	.16	.17	.17	.14	.17	.12
Yield per acre 1/	1.42	1.85	3.17	1.18	2.42	.79
Water use efficiency 2/	.109	.186	.247	.159	.179	.146

1/ Yield, hay in tons

2/ Efficiency = yield per inch of water used, (ET).

J. SUMMARY: Water budget information for 1967 from the lysimeters shows that for the first growth period, water supplied by precipitation was practically the same for all boxes, ranging from 66-70% of ET. For the second period a wider variation is noted (76-144%) with the percentage decreasing in relation to the permeability of the soil. Y103A showed an increase in soil moisture in this latter period, possibly due to a poor stand of vegetation following the first cutting. Crop yield from the first cutting on Y101D was low due to blight infection.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Tillage effects on moisture depletion from corn land.

A comparison of soil moisture and depletion was made in two corn crop watersheds. Watershed No. 187 was cultivated by conventional tillage methods. In watershed No. 191, weeds and grass were controlled by herbicides only and there was no plowing or cultivation. In the former, organic residues were buried by plowing. On the latter, there was a large accumulation of corn stover along with strawy manure applied each year from 1964 to 1968 -- a thick mulch.

Table 2.4 shows the soil moisture depletion for the corn growing season May 25 to September 19 under the conventional-tilled and no-tilled areas.

Table 2.4.-Soil moisture depletion by depths, May 25 to Sept. 19, 1967
(Expressed in inches)

Tillage	Depth								
	0-7"	7-15"	15-21"	21-27"	27-33"	33-39"	39-45"	45-51"	Total
Conventional tillage	1.29	.88	.56	.72	.68	.45	.08	.08	4.74
No tillage	.69	.64	.48	.27	.27	.18	.12	.12	2.77

Moisture fluctuations by the first five different soil depths in the no-tillage and conventional corn areas are shown in figure 2.2. Straight lines connect the points at which field moisture observations were made.

Daily values of soil temperature at the 3" depth (fig. 2.3) shows the effect of tillage on the afternoon (1600 hours) values and the daily fluctuations of temperature between the morning readings (0800 hours) and those of the afternoon. Morning readings were quite similar in both areas.

I. COMMENTS AND INTERPRETATION: Soil moisture in 0-7 inch depth of the no-tillage area depleted to only 24% while under the conventional-tillage, a low of 12% by volume was reached. Greater moisture depletion from all depths through 33" was observed under conventional-tilled corn.

It is interesting to note the effect of the July 2 rainfall of 1.45 inches on the difference between soil moisture recharge in the two treatments (fig. 2.2).

Increase in soil moisture (% by volume) during the period June 29, to July 3, was as follows:

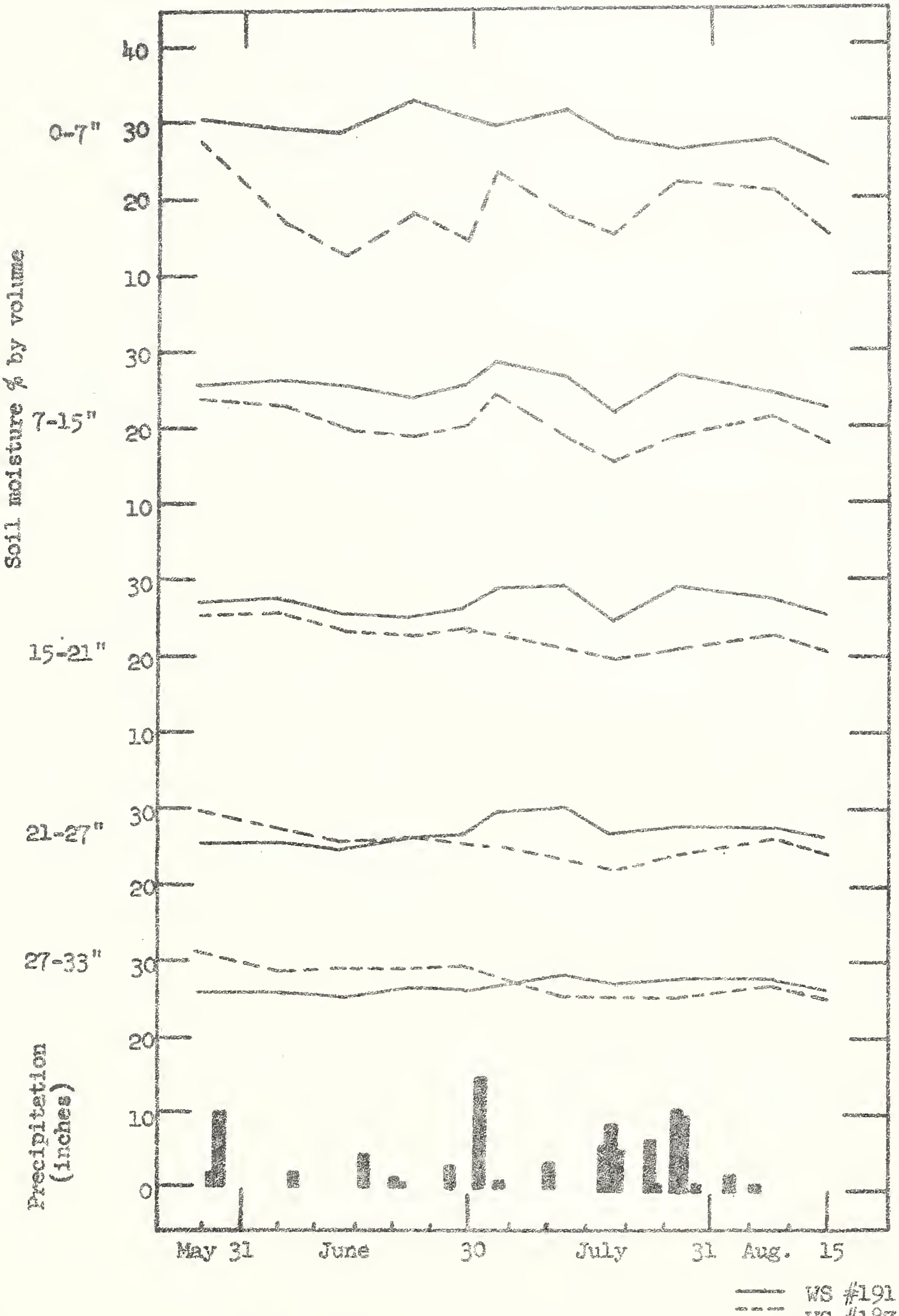


Fig. 2.2 -- Comparison of soil moisture under no cultivation corn (WS #191) and under conventional tillage row corn (WS #187) 1967

Fig. [illegible] — Comparison [illegible]

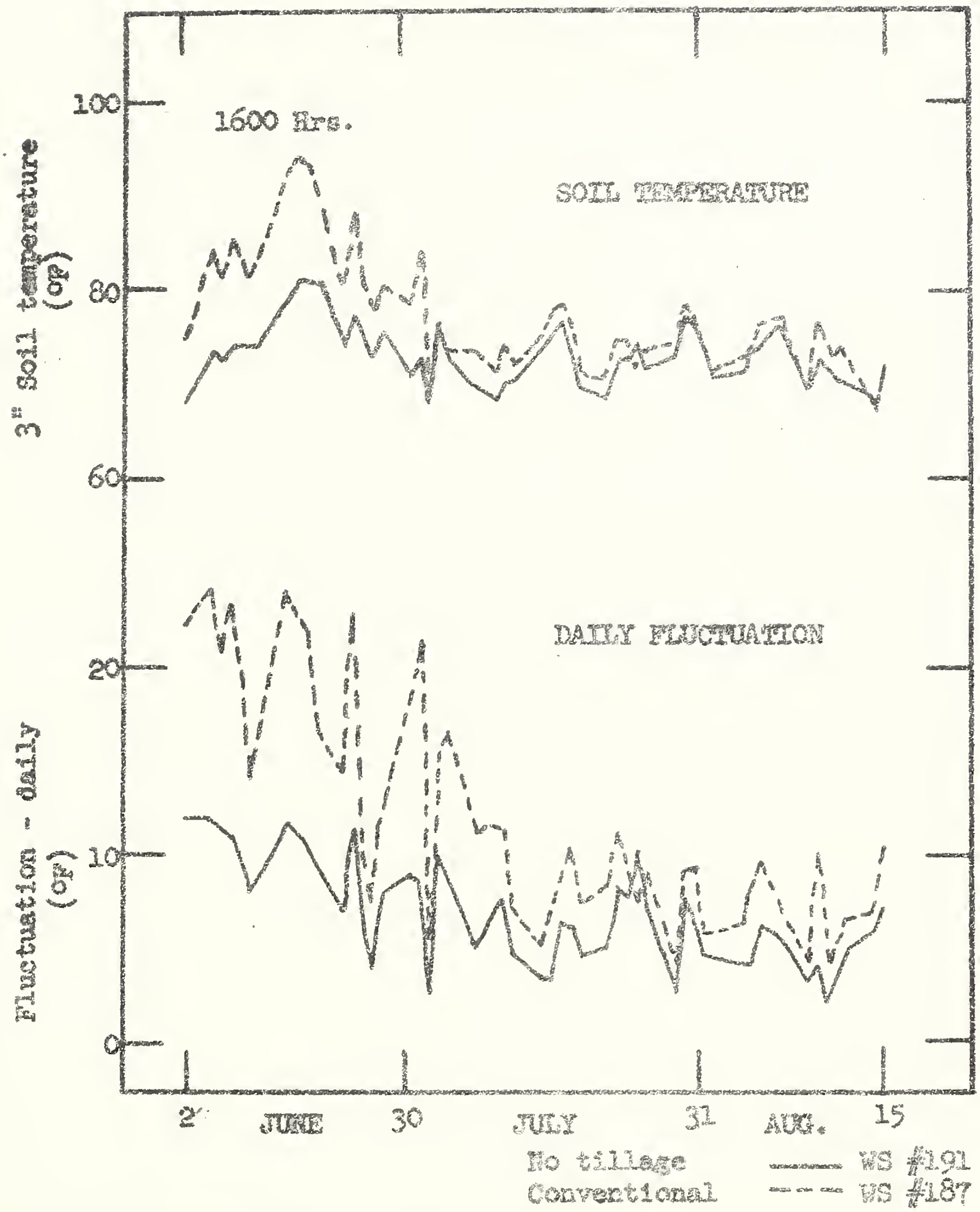


Figure 2.8 -- Afternoon temperatures (°F) and daily at 3" soil depth under conventional tilled and no tilled corn areas, 1967

Soil depth Inches	Conventional %	No-tillage %
0-7	8.5	-0.5
7-15	4.5	2.7
15-21	- .8	2.3
21-27	.1	2.8
27-33	-1.5	.5

Moisture on June 29 in the 7-inch top soil depth of conventional tillage was 15% - having a holding deficit of about 15%. It could, therefore, absorb and hold about 1.05 inch of the rain. There was no holding deficit for no-tillage cornland. Moisture absorbed therefore, drained down to the next four deeper sections of the soil profile. Each showed increases in moisture content during this period. Practically all of the rainfall in conventional treatment was absorbed in the top two sections of the soil profile.

A greater amount of precipitation will be needed to recharge the conventional-tilled corn area, having less moisture in the various depths of its profile, than for the no-tilled field. This indicates that there should be more groundwater recharge - and sooner - under no-tilled than under conventional-tilled corn areas.

The 3-inch soil temperature data showed that during early stages of corn growth the afternoon readings (1600 hours) in the conventional-tilled corn area were higher than for no-tillage corn. During July and August, the temperatures in the two corn areas became similar.

The fluctuation of temperature readings during May and early June were quite large under conventional tilled corn, and gradually it decreases later on. They were mostly larger than in the no-tilled area during the entire growing season.

J. SUMMARY: Throughout the 1967 growing season, moisture content in the root zone was higher under no-tilled than under conventional-tilled corn areas. This was also true in the 1964, 1965, and 1966 growing seasons (See Annual Reports for 1965 and 1966). During storm periods, soil water recharge under no-tilled corn occurred to deeper depths and consequently there was less moisture depletion from these depths. By September 19, soil moisture in the 0-51" depth had decreased by 4.74 and 2.77 inches under conventional-tilled and no-tilled corn areas, respectively. Larger recharge to ground water should occur under no-tilled corn - and it should occur sooner.

Higher afternoon temperature and greater daily temperature fluctuations occurred under conventional-tilled corn. Mulch cover on no-tillage corn probably accounted for the lower temperature, less diurnal fluctuation of soil temperature, and lesser depletion of soil moisture by evapotranspiration.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Soil moisture prediction -- bookkeeping system

The 1965 annual report described the development of a method for budgeting plow layer moisture under meadow (North Appalachian Experimental Watershed Annual Report for the year 1965, page 24). In 1967, 3 more watershed years of measured data were compared with the predicted or estimated soil moisture.

I. COMMENTS AND INTERPRETATIONS:

This bookkeeping system has been tested with nine watershed years representing various soil, cover, and weather conditions. Agreement was good. A report describing the method and its capabilities was prepared.

J. SUMMARY: The following is an abstract of the paper by Youker and Edwards which will be submitted in 1968 to Soil Science Society of America Proceedings for publication:

Simplified Budgeting of Plow Layer Moisture Under Meadow
(Abstract)

Moisture content of the 0-7 inch depth of Keene and Muskingum silt loams under a meadow cover is estimated for the entire growing season based on a known or estimated initial condition in the spring, accretion from rainfall, and depletion from a single composite curve. Daily and hourly changes in water content are budgeted according to a moisture depletion schedule derived from 27 years of soil moisture records.

The depletion schedule is tested with nine watershed years representing various soil, cover, and weather conditions. Correlation between predicted and measured water contents for 120 observations was 0.94 with a standard deviation of 0.20 inch.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Frost penetrometer:

A frost depth gage (penetrometer), figure 2.4, was designed, fabricated, and tested under the direction of W. M. Edwards after a model developed at the National Hydrotechnical Laboratory of the Royal Veterinary and Agricultural College, Copenhagen, Denmark.

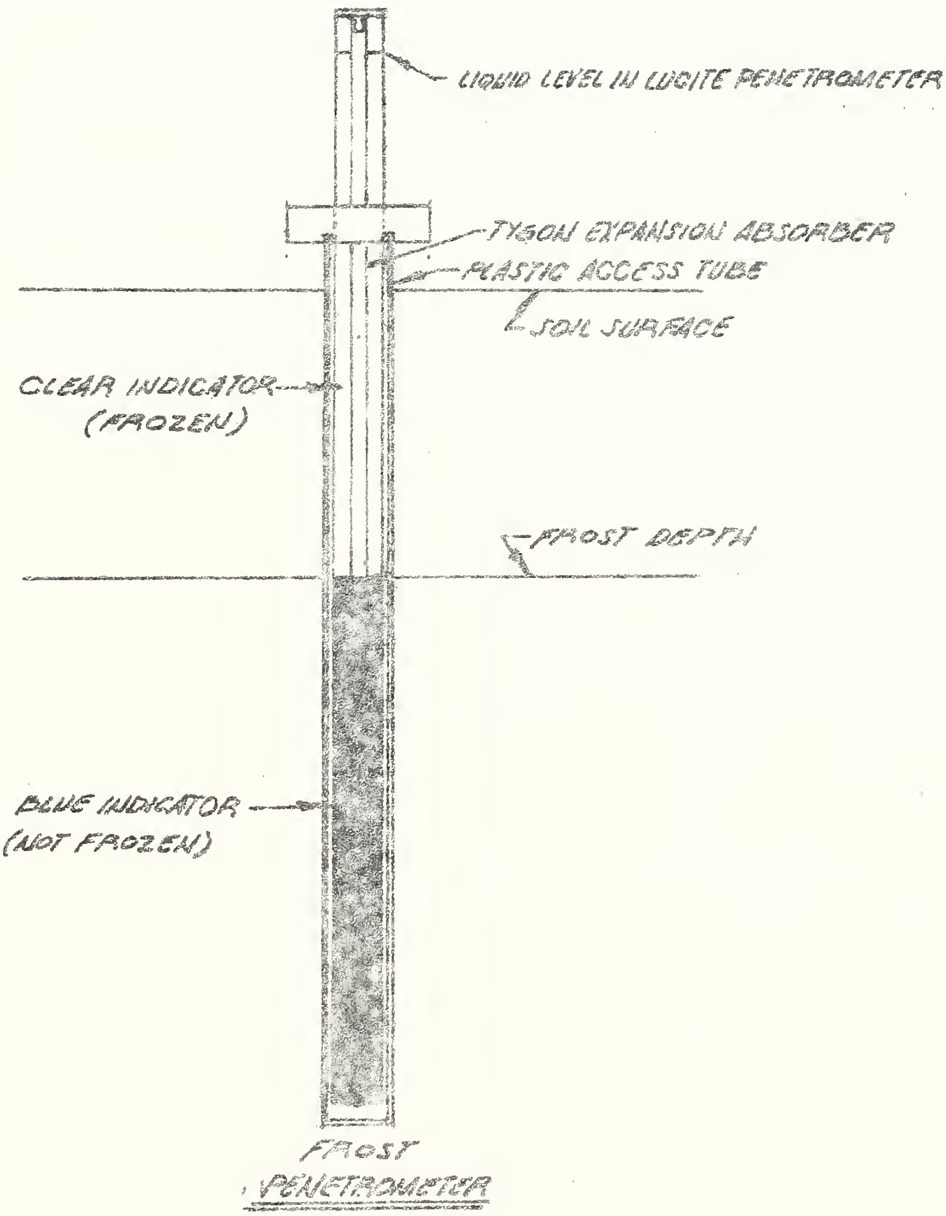


Figure 2.4.-Frost Penetrometer.

I. <u>COMMENTS AND INTERPRETATIONS</u>: It consists of a 1-inch OD clear lucite cylinder, filled with a weak methylene blue indicator solution, mounted in a plastic 1-1/4-inch ID access tube which extends 18 inches into the soil. The indicator solution becomes clear (transparent) upon freezing, thereby indicating depth of frost penetration.

Expansion of the freezing indicator is at the expense of a soft tygon hose inner core. The penetrometer is easily lifted out of the access tube, and frost depth readings made on a scale in inches etched into the clear barrel.

J. <u>SUMMARY</u>: The adequacy of two such frost penetrometers in determining depth of frost penetration under meadow and wheat is currently being evaluated.

A. CRIS WORK UNIT: SWC W4 - cCos-3

Research Outline: Studies in subsurface hydrology, Ohio-3

B. LOCATION: Coshocton, Ohio

C. PERSONNEL: J. B. Urban, W. M. Edwards, L. L. Harrold; cooperator - - Ohio Agricultural Research and Development Center, Wooster, Ohio.

D. DATE OF INITIATION AND EXPECTED DURATION: 1940 - continuing.

E. OBJECTIVES: 1. Determine effects of geology, climate, and land use upon aquifer contributions to streamflow from agricultural watersheds.

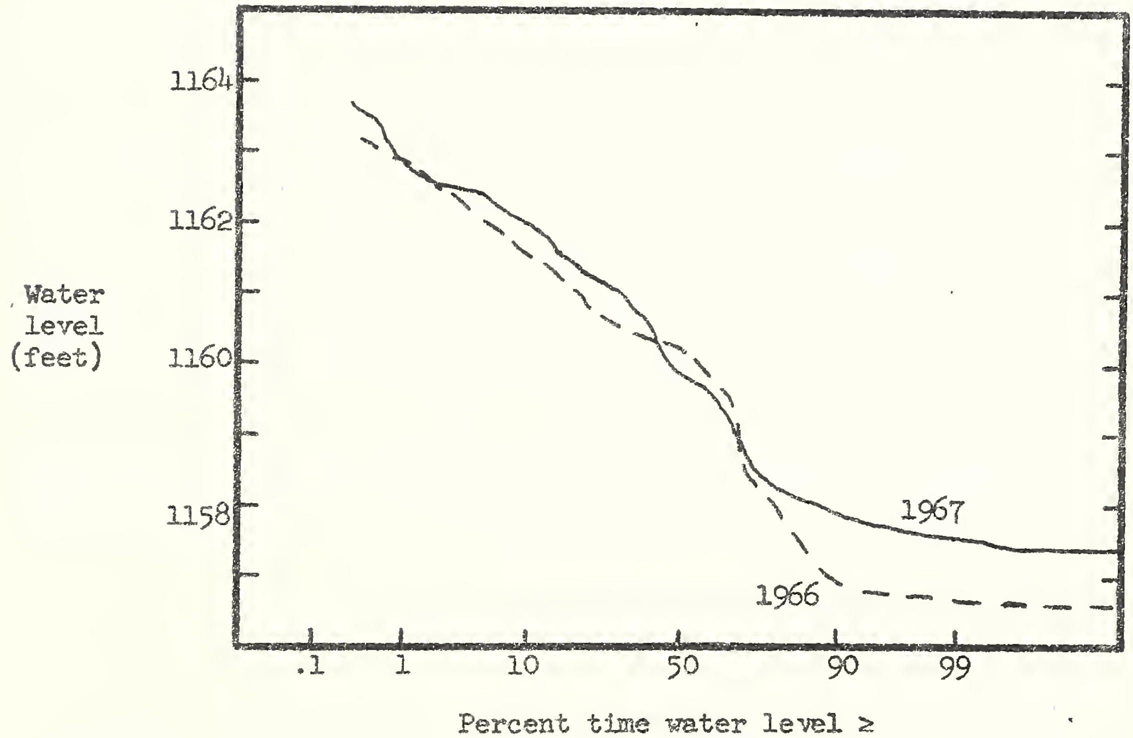
2. Study the fundamental processes of quick subsurface return flow contribution to storm runoff from agricultural watersheds.

3. Study accretion, depletion, and movement of water in aquifers beneath agricultural watersheds as affected by geology and land use and treatment.

F. NEED FOR STUDY: Subsurface and aquifer contributions to streamflow compose a large portion of the total volume of streamflow on watersheds in the Appalachian Plateau. Processes of recharge to aquifers related to climate, land use, soil and geology need to be studied in order to develop hydrologic prediction techniques. Areal extent of underground basins contributing to streamflow must be identified.

G. DESIGN OF EXPERIMENT AND PROCEDURE TO BE FOLLOWED: Geologic strata are identified, mapped, and characterized as to porosity, specific yield, subsurface storage, and outflow. Instruments are installed to record water table fluctuations, recharge, and flow to streams and springs. Chemistry of rock formations, tracers, and aquifer discharge are studied to identify source of flow. Separate hydrologic land and rock units are located and equipped to make complete water balance studies under natural conditions. Techniques are developed for quantifying aquifer storage, recharge, and discharge and relating same to geologic conditions, watershed characteristics, and climate.

H. EXPERIMENTAL DATA AND OBSERVATIONS:
General groundwater conditions - 1967 The seasonal accretion of the February through May period recharged aquifer zones sufficiently to overcome 1966 deficits. Year and water levels stand well above January 1 water levels (fig 3.1).



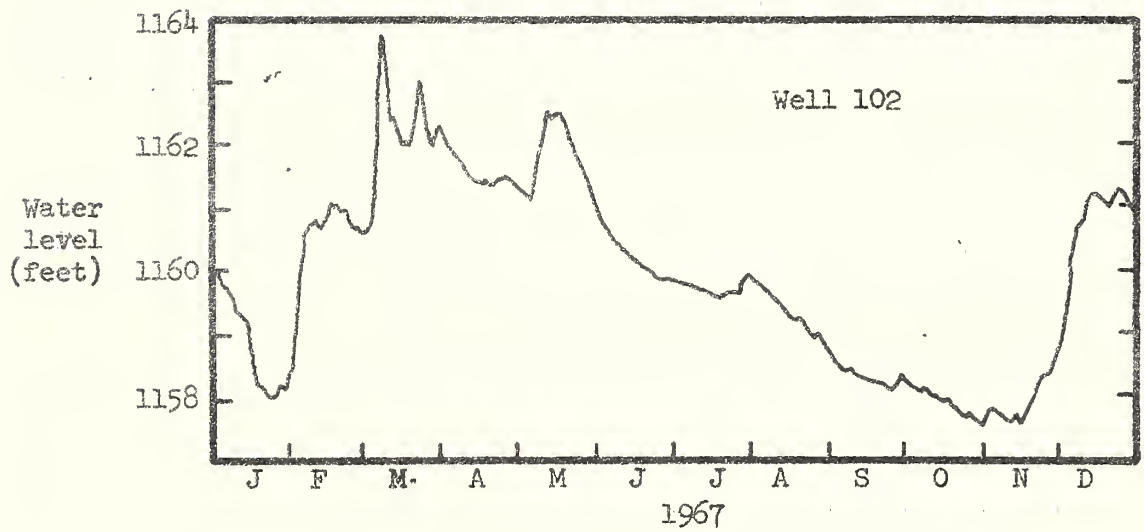


Figure 3.1.-Aquifer storage

Aquifer discharge at springs and seeps continued throughout the year at most sites. Two inches of precipitation in the first week of March brought extremely rapid rises in all wells and springs. Nearly 7 inches of rain in July reduced the normal summer ground water depletion during the growing season.

I. COMMENTS AND INTERPRETATIONS: Substantial percolation during July is an unusual event during any year. Soil water deficits resulting from evapotranspiration demands reduce or stop percolation. The aquifers shown as index aquifers have no well pumpage. Well level records represent a balance between percolation recharge and seepage discharge at springs and to leakage at the outcrop. Water level records indicate the dormant season annually recharges the perched water tables. Only extremely high or low water levels differ greatly year to year (fig. 3.1, top).

J. SUMMARY: Percolation during March and July held water levels in wells at or above normal during the year. Recharge during the midsummer period was an unusual event resulting from nearly 7 inches of rainfall during July.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Geology of aquifers.

The character of the open joint system found in the sedimentary rock strata is important in hydrologic studies, as it is the path of ground-water movement. The nature of the fracture system below the soil and above the perched water is illustrated by water levels near a sprinkler plot and near a pumped well.

Ground-water levels were monitored at nine locations near an interflow plot (fig. 3.2). Well levels were read manually before and after sprinkling runs. Four wells were instrumented with sensitive water level followers to give continuous recordings of water level fluctuations produced by percolation or atmospheric pressure.

The wells are bottomed in the Lower Kittanning clay. The overlying strata are coal, sandstone and shale. The regional joint system trends roughly N 10^{o}W. A silty shale, typically finely fractured, underlies plot #1. The shale unit thins rapidly to the east and at a distance of about 100 feet grades into a sandstone. The water table occurs above the clay in the coal, shale or sandstone units whichever lies above the underclay. Depth to the perched water table is 9 feet. The water mound rises 3 to 5 feet above the clay.

Examination of well level data produced an important and unexpected finding.

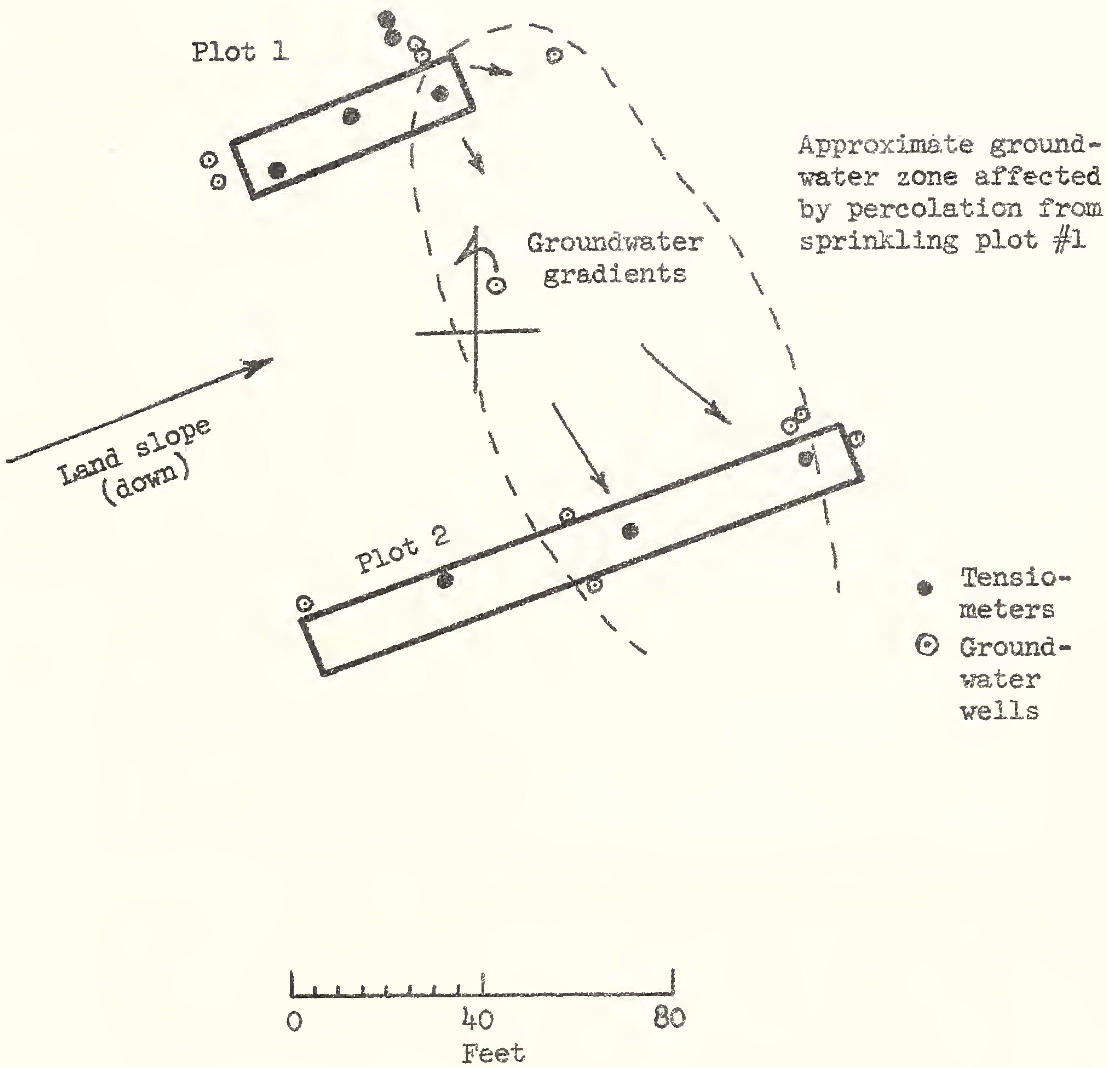


Figure 3.2-Water mound created by percolation from sprinkler Plot No.1.

The percolate apparently did not move in a direct downhill path to the clay outcrop. A water mound created by percolation from sprinkling the plot was not detected directly below the sprinkling area as anticipated. It appeared as a roughly elliptical shaped water mound near the downslope end of the plot and extended mostly to the east and south outside the sprinkler plot, (fig. 3.2). The well log of the observation hole located in the center of the water mound showed a 5-foot layer of massive, well-cemented, fractured sandstone. A major fracture ½ inch wide was plainly visible on the drill hole walls. The fracture trends roughly N 15°W or approximately in line with the regional joint system.

The axis of the water level mound would be roughly N 10° to 15°W. More drill holes are needed to verify the precise ground-water picture.

It seems probable that the joint system has a major influence on subsurface water movement. In addition, the rapid lateral facies change in the rock strata may permit movement of subsurface water along the shale and into the more permeable sandstone.

A similar subsurface flow pattern was found during the pumpage of well #157-20 where the cone of depression developed by pumpage became ellipsoidal with a long axis trending southwest. The geology of the two sites is similar. The minor joint set which trends southwest may have exhibited a more open joint fracture at this location.

I. <u>COMMENTS AND INTERPRETATIONS</u>: Knowledge of the possible effect of joint pattern upon ground-water movement is important in spacing and arrangement of water pumpage wells and observational wells. Aquifer tests based upon the assumption of circular cones of depression underestimate the area dewatered and miscalculate the boundary conditions imposed upon the aquifer system.

J. <u>SUMMARY</u>: Field experiments during 1967 demonstrated that the open joint system in some sedimentary rock strata is coincident with the movement of subsurface water. This finding has important bearing on defining the flow system in watershed studies. It is also an important factor in the location of farm water supply wells in the Appalachian Plateau. Percolation to an upland aquifer was found to form a zone or recharge associated with the trend of fractures or joints in the rock strata.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Hydraulic properties of aquifers: Numerous cores of the fractured rock aquifers showed open joint planes coated with iron cementation. The matrix of the rock, however, does not indicate weathering or deposition of iron precipitates. The lack of cementation in the matrix is recognized as evidence that water moves primarily through the joint or bedding fractures. The effective porosity is practically negligible in all rock units except weathered sandstones. A determination of meaningful hydraulic conductivity or permeability using core samples in a permeameter is subject to enormous error. Flow rates would range from zero to pipe flow-type discharge. Practical application of these values in watershed hydrology studies seems unlikely.

In lieu of core permeabilities, well drawdown tests are used to establish representative field values or aquifer properties. Data and calculations in figure 3.3 and table 3.1 are given for an aquifer test on a perched water table located beneath a ridgetop at the North Appalachian Experimental Watershed.

The pumped well has a 6-inch diameter bore with blank casing to within 8 feet of the impermeable underclay supporting the perched water. In the aquifer zone, the well has a gang-drilled 5-inch casing as well screen. This section is gravel packed with fine gravel between the perforated casing and the water bearing coal and shale.

Low pumpage rates of 2 gal. per minute are required to maintain water levels above the pump screen and yet permit dewatering of the rock. Pumpage rates were maintained by a nozzle arrangement designed and calibrated at Coshocton. Water flow was checked by occasional bucket readings and from a water meter. Water meter readings were in error in initial tests since air passing through the gage registered as fluid flow.

Water level elevations were obtained from FW-1 and Keck water sensor equipment. Water levels are accurate to 0.01 foot. Water levels at the pumped well are subject to greater inaccuracy due to turbulent conditions near the pump intake.

$$T = \frac{264Q}{\Delta s'} = \frac{264 \times 2}{2.88} = 183 \text{ gal/day/ft.}$$

T = transmissibility (gal/day/ft)

Q = well pumpage (gal./min.)

s = well level recovery (ft.)

264 = conversion factor

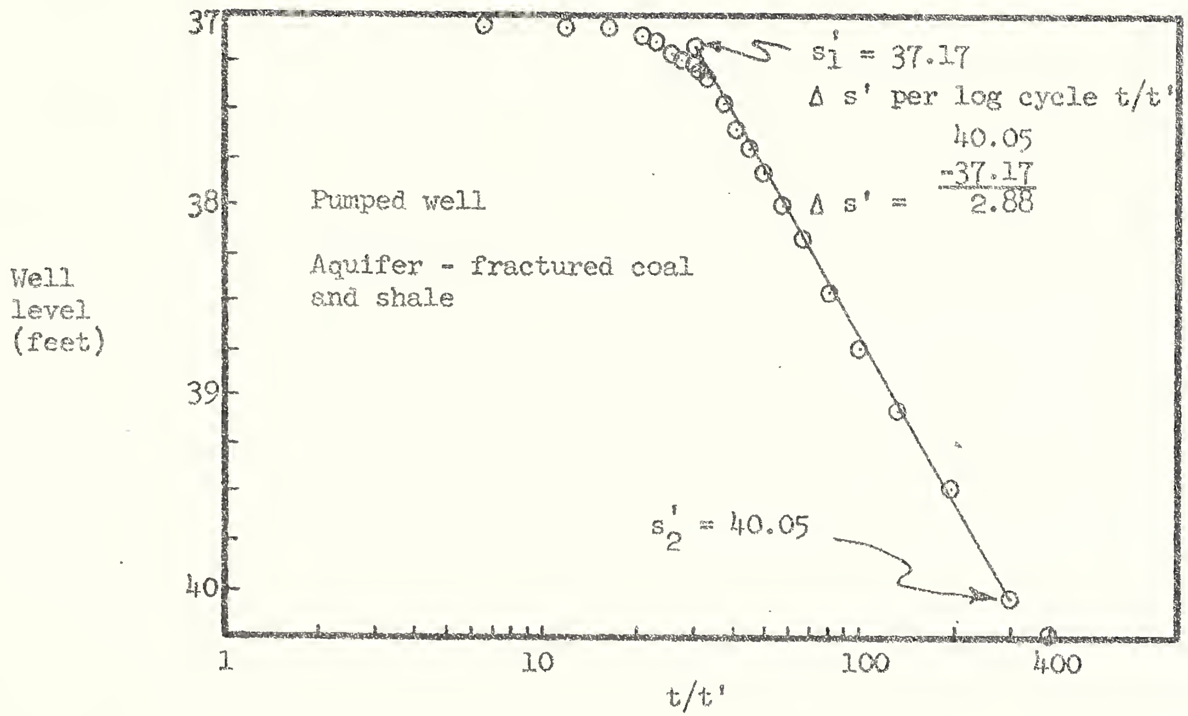


Figure 3.3.-Aquifer test, recovery data for Jacob method illustrating abnormal effects near pumping well.

Table 3.1.-Summary of aquifer test for perched water table in fractured coal and shale

Well level response	Well	Method of analysis	Transmissibility gal./day/ft.	Storativity
Drawdown	Pumped	Theis non-equilibrium	205	0.41
Recovery	Pumped	Theis	170	.28
Drawdown	Pumped well and observation well at 112 ft.	Jacob modified Dupuit	1528	---
Drawdown	Pumped well and observation well at 85 ft.	Jacob modified Dupuit	1335	---
Drawdown	Observation well at 85 ft.	Jacob	1410	.000072
Drawdown	Observation well at 112 ft.	Jacob	1550	.000059

Water levels before and after the pumping test are shown in figure 3.4. The pumping was continued for 3 hours and 15 minutes at the rate of 2 gallons per minute.

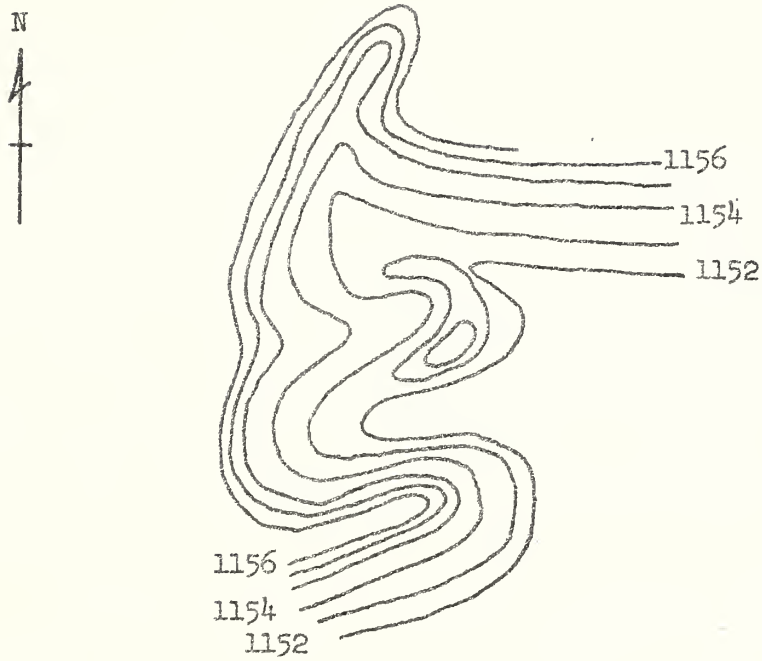
Aquifer coefficients were obtained by applying the following assumptions: homogeneity, isotropy, constant aquifer thickness, laminar flow throughout the aquifer, well is 100% efficient, and the cone of drawdown has reached equilibrium. In actual fact none of these conditions are completely satisfied. Due to the large areal coverage of the pumping test deviations from the ideal are averaged and a particular condition becomes less of a factor in determining overall aquifer properties.

Aquifer drawdown and recovery are analyzed by both equilibrium and non-equilibrium methods.

I. COMMENTS AND INTERPRETATIONS: The determinations of aquifer properties (transmissability and storativity) near the pumped well indicate abnormal conditions which may be due to a reduced permeability near the well. This may be from movement of a clay sealer above the gravel pack into the gravel - well screen zone. It is also possible that the well bore was not completely cleaned of drill fluids prior to installation of the perforated casing. Computed transmissability values for observation holes on the slope of a spur ridge were greater than that for wells on the ridge. Observations in wells close to the divide of the major ridge did not respond to drawdown at the pumped well. This may result from a lack of continuity of fractures. Had pumping continued from 24 or 48 hours the ridge wells may have responded. Further pumping tests are needed to determine the boundary conditions of the aquifer.

J. SUMMARY: The use of aquifer pumping tests in perched water aquifers has provided information of the effect of joint orientation and geologic strata upon ground-water movement. The observations at pumpage sites have revealed complex local boundary conditions such as probable areas of greater permeability and water storage. Computations of yield are based upon uniform porous materials. Estimates of specific yield from the area dewatered by the drawdown cone may be in error due to distortion of the cone of depression around the pumping well. Closely spaced observation wells - 10 to 200 feet from the pumped well are required to define the true shape of the drawdown cone - the area dewatered by a given volume of pumpage.

Transmissability of one Coshocton aquifer was determined to be 1500 gal./day/ft.



Water table contours at start of pumping

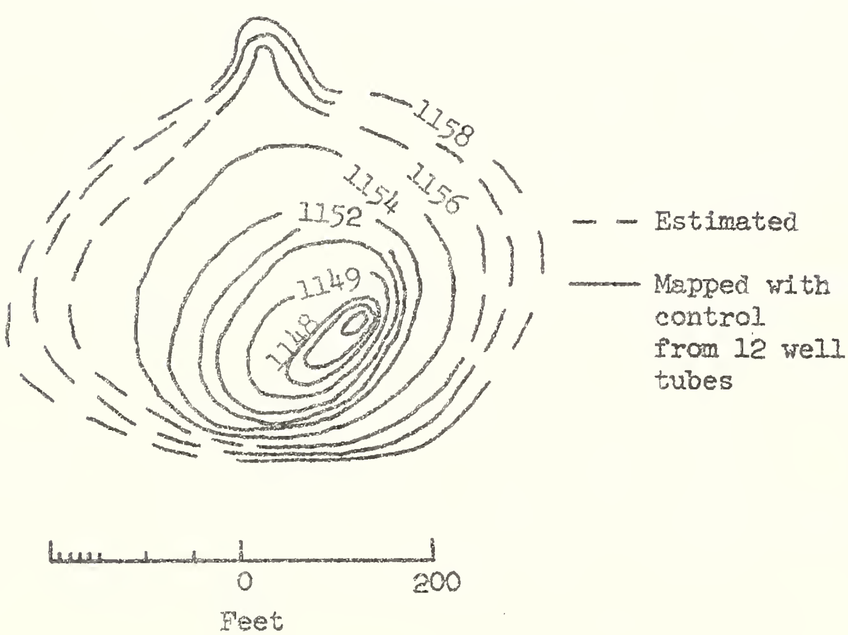


Fig. 3.4.-Effects of well pumpage on a perched water table

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Temperature of groundwater. One of the properties of groundwater useful in water flow studies is temperature. The seasonal variation of ground-water temperature occupies a narrow band near that established by the mean annual air temperature (Collins, W.D., Temperature of water available for industrial use in the United States, USGS, WSP, 520-F, 1925). Collins reported that the annual range of the earth's temperature at a depth of 30 feet may be expected to be less than 1°F. Groundwater occurring at depths of 30 to 60 feet was found to generally exceed the mean annual air temperature by 2 to 3°F. The mean annual air temperature at Coshocton is 50.2°F.

Deviations of water temperature from the "normal" may serve to shed light upon the mechanism of aquifer recharge at Coshocton. Temperature observations were taken with a standard mercury glass thermometer placed in the midpoint of the stream of flow at springs, stream gaging sites, and outlet of mole tube drain. No water temperatures were taken in wells. A thermocouple with leads exceeding 40 feet is needed at most wells.

Observations of spring flow, streamflow, and mole flow were stopped at most sites in July and August. At this time, the water temperatures were affected by high air temperatures at the gage site during very low flows, (i.e.,drip flows at springs and ponded water above the weir).

Water temperatures were taken usually once a week. Streamflow temperatures were taken at two points in the main channel of a mixed cover watershed. The stream is largely a bedrock profile with little alluvium. Flow in spring 106 and the mole tube are derived from perched water bodies underlying the ridge tops. Flow in spring 23 and 20 is from limestone on the lower valley slopes. The mean daily 24-inch soil temperature is taken at an index plot on a ridge top.

Springflow, soil, and streamflow water temperature relationships are shown in figure 3.5. Mean daily soil temperature at 24 inches depth is plotted as is the water temperature for a shallow mole tube discharge and spring 106, a spring developed by trenching and draining the aquifer discharge.

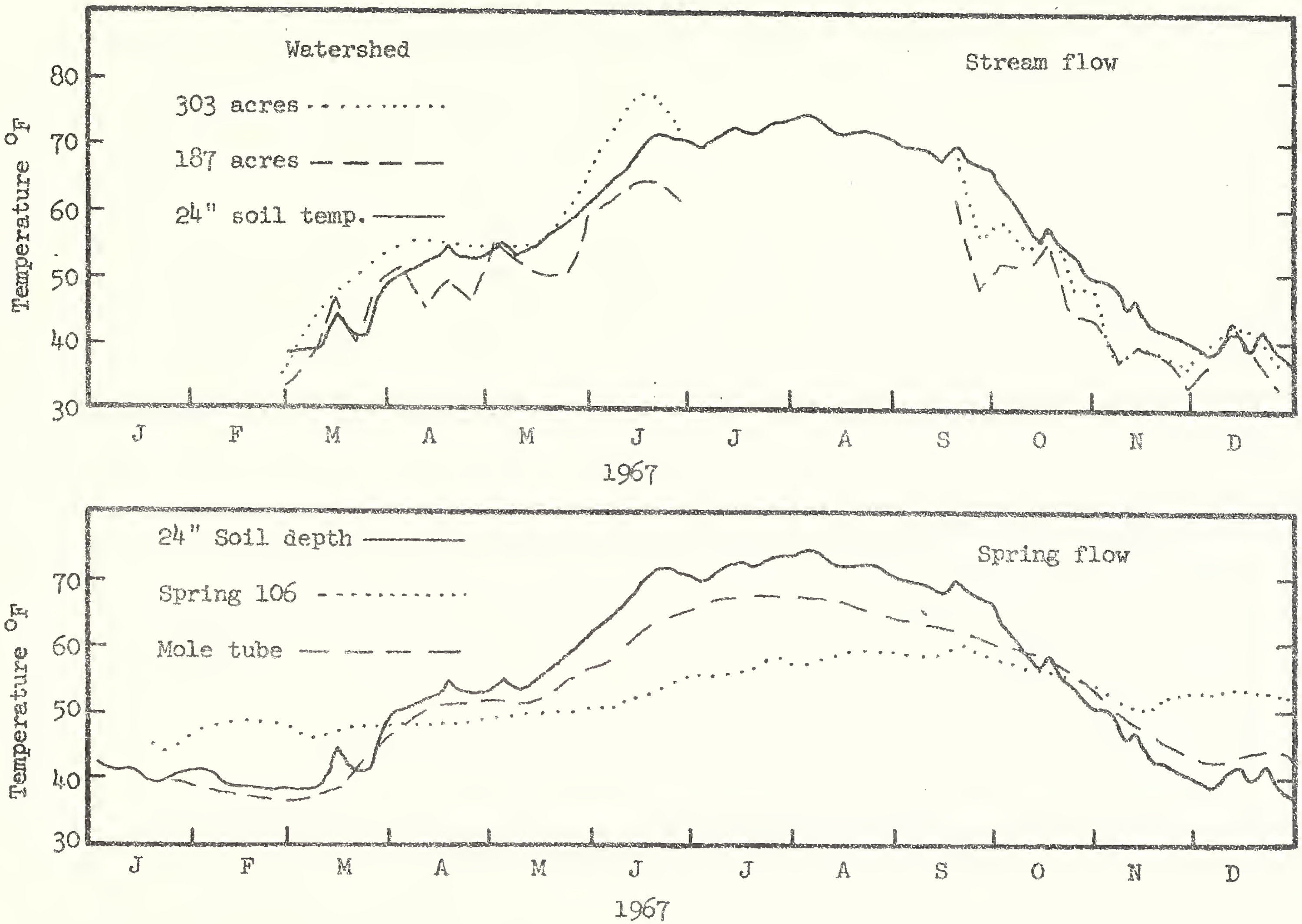


Figure 3.5.- Groundwater, soil, and stream flow temperatures (weekly readings) at North Appalachian Experimental Watershed.

Soil-water temperature is represented by the mean daily soil temperature at the 24-inch depth. This temperature varied from a high of 74.5° on August 5 to a low of 36.5°F on December 31. Temperature of subsurface drainage water, collected in a 2-inch diameter mole tube (See Ohio-3 Annual Report 1966) near the soil-rock interface, followed the general trend of the 24-inch soil temperature. The maximum temperature observed was August 2, 68°F, while minimum temperatures were reached March 1 and December 31 at 36°F. (Table 3.2).

Ground-water temperatures in the aquifer, a coal and fractured carbonaceous shale, are represented by temperature observations at Spring 106 where the collector trench is cut into unweathered shale and coal. Due to the uneven topography the depth to the water table at the trench varies from 14 feet to 4 feet near the outlet. Much of the interceptor trench depth exceeds 8 feet below ground level. The spring is located on the opposite side of a topographic ridge from the mole tube collector. The geology is similar for the two collector sites. Ground-water temperatures in the deep interceptor, Spring 106, ranged from 60°F on September 20 to a low of 43°F on January 25. The temperature exceeded 50°F from June 1 through December 31. The maximum temperature occurred 46 days after the maximum 24-inch soil temperature.

Springflow from the limestone aquifers occurs as a greater and more persistent discharge rate than seeps and springs in the fractured shales, coals and sandstone. This is due largely to the greater storativity of the limestone which is more porous due to ground-water solution activity. The limestone springs occur low in the geologic section at Coshocton and are therefore overlain by the steep valley slopes. Depth of overburden increases rapidly with the slope. However, where the strata dip uniformly to the spring outlet, a long expanse of shallow overburden covers the water bearing strata. Both conditions are exemplified by the following springs. Spring 83 and 23 have dip slopes normal to the hill. Ground-water temperatures at their emergence at spring 83 were: maximum 54°F September 19 and a minimum of 45°F January 31; Spring 23 maximum 54°F on August 30, minimum 46°F January 31. At Spring 20, having dip slopes parallel with topographic contours exposing a long outcrop line, temperatures varied from 40° to 57°F.

Streamflows exhibit a more extreme temperature range than the springs. Despite the many elements influencing stream temperatures, it is surprising to find the range of temperatures near that of the mean daily 24-inch soil temperature (fig 3.5).

Table 3.2.-Observed maximum and minimum temperatures in stream flow, spring flow, and soil for selected months, 1967

Station	Mar.		Apr.		June		Sept.		Oct.		Dec.		Year		Observed range
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	
Stream 196	47	35	55	54	77	71	68	56	58	48	43	36	77	35	42
Stream 194	49	37	49	37	64	61	62	48	55	44	43	33	62	33	29
Stream 174	49	38	51	45	71	67	66	51	58	48	43	33	71	33	38
Spring 23	49	48	50	50	53	52	54	53	53	53	51	50	54	48	06
Spring 20	46	40	50	49	53	52	57	51	53	51	46	43	57	40	17
Mole tube	47	36	52	50	65	57	--	--	58	--	43	42	65	36	29
24" soil	49	38	56	50	72	62	70	67	66	50	42	36	72	36	36

Weir 196 - 303 acres.

Weir 194 - 187 acres.

Weir 174 52.8 acres.

Spring 23 - limestone - deep, short outcrop

Spring 20 - limestone - long outcrop

Mole tube - perforated drain 30 inches deep

I. COMMENTS AND INTERPRETATIONS: Despite the paucity of observations it is clear that the ground-water temperature have a wider fluctuation than a two to three degree range around the mean annual air temperature.

The mixing of soil water with aquifer waters would be a logical explanation for the great temperature variability in some springs. A fairly uniform cover of soil mantles the bedrock providing good bedrock protection from direct atmospheric heat. Spring outlets are protected and shaded affording a minimum of local influence. The response of all aquifers to soil temperatures seems to indicate a dynamic relationship between the bedrock aquifer and the soil water supply. A close relationship of soil water and groundwater infers that the groundwater is probably responding to soil water pressures in a non-steady state flow condition. Low storativity of the aquifer horizons may also enable small amounts of percolation to alter the ground-water temperatures.

Although few springs in various geologic situations were monitored, it appears that the springs exhibiting more sustained flow than others also exhibit a relatively narrow band of water temperatures. Conversely those springs with wide variations in flow rates also exhibit the widest range of temperature.

The sample of water temperatures obtained in 1967 was quite small. More observations are needed on a continuing basis. Observations of water temperatures in wells penetrating the aquifer are also needed to properly identify the temperature of the ground-water body.

J. <u>SUMMARY</u>: Weekly observation of ground-water temperatures from springs and streams were taken in 1967. Ground-water temperatures appeared to be more sensitive to soil temperatures than expected. Springs exhibiting sustained discharges with little variation also exhibited a narrow band of water temperature. A large storativity of the aquifer may be a major factor in reducing the temperature fluctuation. Low storativity of the aquifer, conversely, may be a major factor in permitting large temperature fluctuations in spring flow. Results of preliminary investigations show the possibility of using water temperatures as indicators of aquifer properties.

H. EXPERIMENTAL DATA AND OBSERVATIONS:
Hydraulic conductivity of soils. The hydraulic conductivity of soil materials at Coshocton was investigated with a double tube permeameter. Values of conductivity ranged from zero to .047 cm/min. Water transmission through subsoil horizons in Keene silt loam was too slow to be measured with the present equipment. A wide range of conductivities was observed in the 0 - 7" topsoil.

I. COMMENTS: The double tube permeameter (H. Bower, January 1964) was used as a means of obtaining insitu saturated conductivities in watershed soils. The determinations of the soil horizon water transmission properties are of major interest for studies of interflow and water percolation rates to groundwater.

The double tube was initially placed in the outcrop of an underclay to determine if measurable water transmission occurs through the underclay. During the initial wetting, a small quantity of water was transmitted which may have been a filling of storage along the walls of the sampler. After nine days of wetting under approximately 7 feet of water head, no water transmission from the permeameter was observed.

Due to the compact nature of the clay no piezometer readings were attempted. The piezometers would doubtless have been dry in any case.

During much of the field season, efforts were made to eliminate instrumentation problems and obtain the saturated hydraulic conductivities of the major soil types present at the research station. Some of the problems and solutions in using the double tube are listed.

A. Roots and root holes provide piping conditions for water to move rapidly through the soil. As the soil reaches saturation the saturation check, $S = \frac{t_{OTS_1} - t_{EL}}{\left(t_{EL}\right)^2}$ becomes highly variable. Water intake rates become quite large and the fit between soil and outer cylinder erodes until water flows through the eroded passageways of root holes to the surface. While the problem is easily recognized, the only solution seems to be moving to a site where no roots are present - then the question arises as to the representativeness of the results.

B. Time readings in the early stages of dropping either inner or outer tube standpipe water levels are subject to error. Small errors in time are raised geometrically as noted in the above equation where time of equal levels (t_{EL}) is $(t_{EL})^2$.

C. Piezometers (perforated 1/2" black pipe) placed beneath the double tube permeameter at one site exhibited changes in head during a prolonged saturation check that may be due to a changing geometry of the saturated area beneath the double tube.

D. The piezometer arrangement designed as part of the double tube equipment becomes plugged in most silty or silty clay soils at Coshocton. Several design changes were attempted with little success. Smearing of the well screen by soil colloids may be a major contributor to piezometer failure.

E. The quality of water used in the permeameter appeared to have some effect on infiltration. Stream water and treated well water from the research station wells was replaced by deep well water from a sand aquifer (untreated).

F. An unusual effect was noted at a site in sandy alluvium. The intake rate of water at the permeameter varied throughout the day, principally morning and noon. The long period of wetting (48 hours) at the site should have been sufficient to bring the soil to near saturation beneath the permeameter. Temperatures in the air ranged from 80°F to 62°F. Temperatures of the supply water were higher in the standpipes than in the soil. (Air 73°F, water supply 60°F, inner tube standpipe 73°F, outer tube 65°F). Perhaps as air temperatures varied, water viscosity changed. Another factor might be barometric pressure acting upon entrapped air within the zone of saturation causing increased or decreased storage in the soil column beneath the permeameter.

<u>SUMMARY</u>: Initial field trials of a double tube permeameter were conducted at Coshocton.

Due to soil effects (sealing, plugging, etc.) at the permeameter piezometers, no determinations of horizontal conductivity were made. Vertical conductivity determinations varied widely in the silty topsoil. No conductivities were determined for the silty clay subsoils which did not appear to be sufficiently permeable to be measured by the apparatus in its present design.

A. CRIS WORK UNIT: SWC W3-cCos-2

Research outline: Runoff studies of unit source area watersheds, Ohio-4

B. LOCATION: Coshocton, Ohio

C. PERSONNEL: C. R. Amerman, J. L. McGuinness, W. M. Edwards, and L. L. Harrold; cooperator -- Ohio Agricultural Research and Development Center, Wooster, Ohio

D. DATE OF INITIATION AND EXPECTED DURATION: 1940 - continuing

E. OBJECTIVES: 1. To evaluate the factors affecting the value of storm surface runoff from various combinations of soil, cover, and treatment.

2. To study the basic factors affecting the hydrograph of surface flow for soil-cover combinations.

F. NEED FOR STUDY: Unit source watersheds are small enough that many of the physiographic and land use factors affecting surface runoff can be isolated and evaluated. The possibility of using their data, along with related values from subsurface flow, to synthesize flow from complex watersheds needs to be evaluated.

G. DESIGN OF EXPERIMENT AND PROCEDURE TO BE FOLLOWED: The field experiment consists of 20 natural watersheds of 0.65 to 2.68 acres on Muskingum silt loam (well drained) and Keene silt loam (slowly permeable) and slopes of 6 to 22 percent. Those over 16 percent slope are in permanent grass or woods. Watersheds are treated as shown in table 4.1.

The effect of crop, management, soil moisture, and watershed characteristics and conditions on rainfall-surface flow relationships are evaluated. Those advanced improved practices on watersheds listed in column 4 that show promise of causing significant changes in these relationships may be installed on those watersheds listed in column 3 in table 4.1 and the basic comparisons continued. Initial trials of additional new practices will then be set up on watersheds listed in column 4.

Investigations will be made of the possibility of locating and instrumenting unit source watersheds in wet areas down slope from the major watershed divide in order to establish rainfall-runoff relationships for segments of the hydrologic flow system where partial-area contributions to streams of complex watersheds are likely to be sizable. The isolation of segments of the flow system must be made without disturbing or destroying the natural system.

Table 4.1-Land use on designated unit source watersheds

Year	Basic rotation[1/] of corn, wheat, meadow-1, meadow-2		Advanced practices on cornland 2/	Wood-land	Grass meadow	Pasture	
	Prevailing	Improved				Prevail-ing	Improved
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1967	118	113	111,191	131,132	130	135	102,129
1966	110	103	128,191	131,132	130	135	102,129
1965	115	109,123	127,191	131,132	130	135	102,129
1964	106	121	188,191	131,132	130	135	102,129
1963	118	113	111,191	131,132	130	135	102,129

1/ Cornland: Spring plowed 7 inches deep, disk, disk, harrow, plant, cultivate 2 or 3 times, harvest with picker, shred stover.

Wheatland: Disk and plant in fall, harvest in July. Grass and legume seeded in wheat.

2/ Mulch, minimum tillage, no tillage, pollution studies, etc.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Tillage effects on volume weights:

Meadow on watershed 188 was plowed to a depth of 16 inches (9 inches greater than normal) in May 1964. Corn was planted without seedbed preparations. Volume weight determinations (table 4.2) following corn harvest in 1964, after wheat harvest in 1965, at end of first-year meadow growing season in 1966, and at end of second-year meadow growing season 1967, show that the loosening effect had not greatly diminished 29 months after plowing (May 1964 - Oct. 1966) but by September 1967, density in the 10-13" and 13'16" depths was nearing that under normal tillage. Tillage operations subsequent to corn harvest in 1964 were chopping of corn stalks, disking for wheat, and seeding -- a minimum.

Table 4.2-Volume weights of soil in deep-plowed watershed 188 related to those of normal tillage

Depth	Deep plow								Normal tillage			
	Nov.1964		Sept 1965		Oct.1966		Sept 1967		Sept 1967		Average	
Inches												
0-3	1.33±0.02		1.24±0.01		1.32±0.05		1.24±0.03		1.35±0.03		1/ 1.25±0.02	
4-7	1.36	.05	1.22	.03	1.30	.01	1.16	.04	1.33	.02		
7-10	1.21	.01	1.25	.04	1.22	.06	1.16	.04	1.33	.03	2/ 1.47	.01
10-13	1.28	.01	1.20	.04	1.28	.03	1.40	.02	1.45	.04		
13-16	1.53	.03	1.26	.01	1.28	.02	1.42	.04	1.56	.08	3/ 1.65	.02
16-19	1.54	.03	1.52	.05	1.55	.04	1.52	.02	1.52	.10		

1/ = 0-7"; 2/ = 7-14"; 3/ = 14-24"

The reason for deep plowing was to explore the possibility of increasing the depth of rapid water absorption during local intense summer rain storms. No high-intensity storms have occurred to cause significant runoff or fill the soil pores in this period of study.

Volume weight values at corn harvest time for topsoil on a no-tillage, continuous corn watershed, along with comparable values from 4-year rotation conventional plowed watersheds, for the period 1964-67 are given in table 4.3. Although four different watersheds were

Table 4.3.-Volume weight of topsoil in no-tillage and conventional plowed corn watersheds, 1964-67

Date	Continuous no-tilled corn				Conventional tilled corn			
	Depth				Depth			
	0-3"		4-7"		0-3"		4-7"	
Nov. 1964	1.37	± 0.04	1.40	± 0.03	1.25	± 0.04	1.33	±0.02
Sept. 1965	1.39	.01	1.37	.03	1.43	.03	1.40	.05
Oct. 1966	1.38	.02	1.37	.01	1.24	.04	1.40	.03
Sept. 1967	1.39	.03	1.37	.01	1.04	.02	1.18	.08
Variation	.02		.03		.39		.22	

sampled for the conventional-tillage values, soil was basically the same. Volume-weight values for the no-tillage watershed for all 4 years are almost identical. There is little difference in values either with time or with soil depth. Conventional plowing and subsequent tillage operations in the corn season introduced greater variability in volume-weight values, as expected. In this case, the

size of the variability between replicated samples of the 4- to 7-inch profile -- taken at the same location and date were as large as ± 0.08 -- much larger than those for no-tillage corn, ± 0.03. However, the variability of samples in the 0- to 3-inch depth were 0.04 or less -- not greatly different than those in no-tillage corn.

The effect of tillage on soil moisture under these treatments reported under SWC W3-cCos-2, Ohio-2.

I. COMMENTS AND INTERPRETATIONS: Although the density of the deep-plowed soil in the 10- to 13- and 13- to 16-inch depths decreased in the 4th year after deep plowing it was still less than normal. That at the 7- to 10-inch depth lost none of its looseness in the study period. There remained over a 4-year period a sizable increase in storm rainfall absorption potential over that in normal (7-inch) plowed field.

This watershed sod will be plowed to a depth of 16 inches again in 1968 - the soil will again be loosened and observations continued.

As the depth of plowing relates closely to rapid storm rainfall absorption, the lesser volume weight indicates that deep plowing might have a noticeable effect on reducing flood flows from agricultural watershed. This is speculation and yet to be researched.

In the no-tillage, continuous corn watershed, volume-weight values at harvest time remained essentially constant over a 4-year period. Although there were no tillage operations to loosen the soil and very little tractor compaction, there was no noticeable increase in density with time. Data showed that at corn harvest time, there was no consistent difference in density values between the no-tillage and conventional plowed watersheds. There was, however, greater variability in volume-weight values for individual replicate samples of the 4- to 7-inch profile in 3 out of 4 years - possibly the result of variation in plowing. Variability in the 0- to 3-inch values for the two practices and between the years were not materially different. Tillage following plowing tends to eradicate differences in replicates of samples taken in the surface 3-inch depth.

Corn crop on no-tillage corn showed the effect of lack of nitrogen in 1967. This was the first year of the four years of record when no extra nitrogen was applied. The build up of organic matter on the land surface of this watershed from corn stover and manure resulted in nitrogen deficiency in the corn crop. Had extra nitrogen been applied, the 1967 yield could have reached 140 to 150 bushels per acre. Corn yields are given in table 4.4 for both conventional and no-tillage watersheds for the period of study.

Table 4.4.-Yield on no-tillage continuous corn watershed

Year of corn	Conventional rotation 1/ #185	Conventional rotation 1/ #187	Continuous corn #191	Extra nitrogen 2/ #191
	Bushels/acre	Bushels/acre	Bushels/acre	Pounds/acre
1964	95	--	136	37
1965	--	91	106	90
1966	110	--	117	90
1967	--	134	109 3/	0

1/ Corn strips in watershed; 4-year rotation, corn, wheat, meadow, meadow.

2/ Broadcast urea about planting time.

3/ Nitrogen deficiency apparent.

J. SUMMARY: Plowing to a depth of 16 inches loosened the soil in May 1964 and the effect appears to have lasted through the 1965 and 1966 growing seasons. By the end of the 1967 growing season the soil volumes in the 10-13- and 13-16-inch depths appear to be approaching that of normal tillage.

No-tillage continuous corn maintained a fairly constant volume weight for 4 years after the start of the test -- in the 0- to 3-inch and the 4- to 7-inch depths. At corn harvest time, volume-weight values for both soil layers were not materially different for either practice. Replicates for the lower layer in the conventional plowed and tilled watershed showed greater variability, however.

Reported by:

R. E. Youker

R. E. YOUKER
Hydraulic Engineering Technician

A. CRIS WORK UNIT: SWC W8-cCos-5

Research Outline Sediment production from unit source area watersheds, Ohio-5

B. LOCATION: Coshocton, Ohio

C. PERSONNEL: R. E. Youker; cooperator - Ohio Agricultural Research and Development Center, Wooster, Ohio.

D. DATE OF INITIATION AND EXPECTED DURATION: 1940 - continuing

E. OBJECTIVES: 1. To characterize sediment production of various soil-cover combinations.

2. To study the basic factors affecting sediment production.

F. NEED FOR STUDY: Erosion data from whole natural watersheds are needed to evaluate the effect of land use on sediment sources and delivery ratios -- data important in the design of reservoirs and stream channels. These data are also needed as a comparison for erosion values developed from erosion prediction equations.

G. DESIGN OF EXPERIMENT AND PROCEDURE TO BE FOLLOWED: Samples of suspended sediment in runoff are obtained for each storm by Coshocton type wheel samplers on corn watersheds. Sediment deposits in the flume and its paved approach are quantified and sampled. Laboratory analysis is made of the suspended material to determine the dry weight per unit volume of runoff sample and deposited material to determine total dry weight per storm. The resultant values from runoff samples are applied to flow data to derive erosion values for storms, seasons, and years. Erosion values from wheat, grass, and woodland have been so small as to no longer require measurement.

H. EXPERIMENTAL DATA AND OBSERVATIONS: Insignificant amounts of sediment in 1967 due to low rates of rainfall.

I. COMMENTS AND INTERPRETATIONS: None

J. SUMMARY: None

A. CRIS WORK UNIT: SWC W6-cCos-4

Research outline: Studies of runoff from complex watersheds, Ohio-6

B. LOCATION: Coshocton, Ohio

C. PERSONNEL: L. L. Harrold, J. L. McGuinness, J. B. Urban, W. M. Edwards; cooperator - Ohio Agricultural Research and Development Center, Wooster, Ohio.

D. DATE OF INITIATION AND EXPECTED DURATION: 1940 - continuing

E. OBJECTIVES: 1. To determine how flows from incremental areas combine to produce hydrographs of streamflow on larger watersheds.

2. To determine the effects of watershed characteristics on rates and amounts of runoff.

3. To develop procedures for predicting the magnitude and frequency of flows from ungaged watersheds.

F. NEED FOR STUDY: Basic data and procedures by which the magnitude and frequency of flood flows and water yield can be estimated are needed for ungaged watersheds of a few acres to several hundred square miles in size. Present procedures are based on limited research information and field observations.

Hydrologic data from complex watersheds are needed as predictive and control factors for water budgeting and development of watershed model techniques for predicting flood flows and water yield.

G. DESIGN OF EXPERIMENT AND PROCEDURE TO BE FOLLOWED: The entire flow system of a complex watershed is to be put together piece by piece as the individual segments are identified, quantified and related to climate, crop, land use, soil, and geologic conditions. Flow volumes for storms and months synthesized in this manner are compared with measured values at stream gages for watersheds of the following sizes:

* 29 acres	349
* 43	373
* 75	920
122	1520
292	2570
*303	17500

*Located on government-controlled land. All others are on privately-owned land.

Predictive techniques are developed to show the effect of physical characteristics and land use changes on rainfall-runoff relationships.

H. EXPERIMENTAL DATA AND RELATIONSHIPS:

Minor relocation of stream gage affected values of monthly water yield and peak flows. Streamflow records from gage 177 at the outlet of a 75.6-acre watershed showed very little base flow. The stream ceased flowing for months during most August-October periods, whereas there was flow in the same channel 150 feet downstream. Apparently some water yield from the basin was escaping underground and was not measured by this gage.

Another stream gage (166) was installed September 29, 1966 220 feet downstream where dry weather flow persists. Geologic drillings showed that a weir located at this point could be based on an impermeable natural underclay and its flow record would better represent total yield of water from the agricultural basin. The surface area of this new watershed is 79.2 acres, an increase of 3.6 acres.

Monthly runoff and peak flow values from these two gages are given in per unit of area units in table 6.1.

Table 6.1--Monthly runoff and peak flows from gages 177 (75.6 acres) and 166 (79.2 acres), 1967

Month	Runoff total		Peak flow	
	WS177	WS166	WS177	WS166
	Inches	Inches	Inch/hour	Inch/hour
Jan.	0.0416	0.0346	0.0014	0.0015
Feb.	.4931	.6520	.0055	.0054
Mar.	3.4470	3.9873	.0539	.0605
Apr.	.6835	.9969	.0213	.0213
May	1.4889	2.1645	.0449	.0486
June	.0056	.0569	.0001	.0004
July	.1528	.2183	.0163	.0158
Aug.	.0024	.0314	T	.0005
Sept.	.0250	.0471	.0043	.0054
Oct.	.0034	.0355	.0011	.0008
Nov.	.1107	.2246	.0041	.0048
Dec.	.9557	1.3031	.0303	.0338
Year	7.4097	9.8022	---	---

I. COMMENTS AND INTERPRETATIONS: The relocation of a stream gage 220 feet downstream to the outcrop of impermeable geologic strata made it possible to measure streamflow approximating the values of total watershed yield. Data in table 6.1 show that new gage 166, situated on an underclay, measured 32 percent more annual water yield per unit of area than that of old gage 177 located 220 feet upstream, but with its base 15 feet in elevation above the underclay. Runoff volume differences were all in this same direction and material every month of the year. The largest differences were 0.676 inch in May; 0.540 in March, and 0.347 in December. In relation to the values from the new gage, those at the old gage site were 31, 14, and 26 percent low, respectively. Differences in the months of low flow are relatively small in quantity, but large in percent -- as much as 90 percent of the flow at 166.

Peak flow values for the various months were affected little by the relocation of the gage. As these flows are generally associated with flow from storm rainfall, the location of the gage apparently had little or nothing to do with the results of storm rainfall-runoff studies. It is likely, therefore, that the old gage was measuring storm water adequately but that it was missing the sustained flow portion of the total water yield.

Studies of the effect of land use and treatment on water yield of watershed 177 as reported in USDA Technical Bulletin 1256, could not, under these circumstances, represent the entire effect on sustained flow. This Bulletin called attention to this shortcoming. However, it reported that the effect of land use and treatment (reforestation) on another watershed was most noticeable on the sustained portion of that water yield. (In this case, the gage location was such as to measure total yield). The effect of land management change on watershed 177 as reported, would not be expected to be smaller by using data from 166, but it could be larger. Future land management changes on watershed gaged by 166 can now be properly evaluated -- as total flow is now measured.

J. SUMMARY: The relocation of a stream gage, 300 feet downstream where it could be tied into an underclay, made it possible to measure total water yield from an agricultural watershed. The old gage location measured only part of the total flow -- much of the sustained flow bypassing in the valley alluvium and fractured rock. The largest quantitative differences -- 0.68 inch in May, 0.54 in March, and 0.35 inch in December occurred when the flow values at the new site were 2.16, 3.99, and 1.30 inches, respectively.

Flow at the old site was short by 31, 14, and 26 percent.

The effect of gage location on sustained flow values was quite noticeable -- although small in size. The differences in June, August, and October, when water supplies are normally deficient, were in the order of 90 percent -- the old site missing 90 percent of the water yield.

Storm water flow values at the old gage site were not noticeably different than those at the new site. Studies made thereon should not therefore be affected by site. Water yield studies in the past are not adequate, as they involve only part of the sustained flow. Studies of the effect of land management on total water yield will be more complete as they will be based on data from the new site.

A. CRIS WORK UNIT: SWC W3-cCos-2

Research outline: Study of interflow related to precipitation and soil moisture, Ohio-8.

B. LOCATION: Coshocton, Ohio

C. PERSONNEL: C. R. Amerman, J. B. Urban, J. L. McGuinness, and W. M. Edwards: cooperator - - Ohio Agricultural Research and Development Center.

D. DATE OF INITIATION AND EXPECTED DURATION: 1961 - continuing.

E. OBJECTIVES: 1. Investigate the threshold combination of soil moisture and precipitation parameters at which interflow begins.

2. Investigate effect of antecedent soil moisture on rates and volumes of interflow for given precipitation rates and volumes.

3. Investigate movement, distribution, and head variation of soil moisture in soil zones above and below the zone of interflow during interflow.

F. NEED FOR STUDY: This need is presented in the 1962 Annual Report. As the flow of water through soils may be an important factor in both storm runoff and base runoff, it is necessary that its occurrence be studied and that methods of measuring its parameters be developed.

G. DESIGN OF EXPERIMENT AND PROCEDURE TO BE FOLLOWED: The experiment is based upon the concept that during and immediately after storm periods shallow, rapid, subsurface water movement, called interflow, occurs in the soil and weathered rock profile and contributes to the direct storm runoff portion of a stream hydrograph. As direct storm runoff recedes after the storm, drainage continues from the soil profile in a manner similar to base flow. The mechanism of this water movement is not well understood. Theoretical formulae describing boundary conditions and discharge flows are applicable to uniform soil conditions and to regular geometries seldom encountered in the field. Further, they apply either to one-dimensional flows only or to fully saturated flow in two dimensions. Field data are gathered to relate hydrologic, soil, and geologic factors to interflow threshold conditions. Laboratory and analytic methods serve to assist in interpretating the data. Threshold conditions may be simulated by sprinkling or may occur from normal precipitation events.

The present field experiment consists of a 0.64-acre field watershed and two sprinkler plots. All sites are defined by shallow clay core dikes, and are cut off at the lower end by trenches having collector troughs at prominent soil horizons. All sites are equipped to measure water input (natural or artificial), surface and subsurface runoff and groundwater storage as indicated by well level records. Soil moisture at subsequent depths to the bedrock is measured in the A_p horizon with gypsum-fiberglas resistance blocks and by neutron scattering devices. Water gradients in the soil of the two plots are monitored by batteries of rapid response, recording tensiometers.

Instrumentation designs for monitoring rapidly changing soil water conditions in situ are to be developed. Soil hydrologic properties - the moisture characteristic and saturated and unsaturated conductivity - are to be determined for use in determining the total moisture flux. Field boundary conditions are to be determined as an aid to defining the total flow region.

Physical measurements are made to identify field boundary conditions. Laboratory and mathematical models are developed to test predictive techniques and working hypotheses as part of a hydrologic system.

Model studies are used to guide the layout of field sites for checking theoretical design, i.e. the effect of possible upslope soil water drainage due to the construction of open catchment trenches at gaged interflow plots.

H. EXPERIMENTAL DATA AND OBSERVATIONS: Plot studies of runoff from surface and subsurface collectors during the summer of 1967 indicated that interflow may occur at depths of several feet. Subsurface discharge during sprinkler-induced storm events was measured at the base of the topsoil and within the subsoil. Hydrograph analysis of the data has not been completed. However, an obvious effect of controlled runoff upon a plot with high antecedent moisture was to fill the storage reservoir in the 0-7 inch topsoil. Water in excess of storage and deep percolation returned to the surface at the lower end of the plot. This contribution appeared to augment surface runoff after sprinkling was stopped.

The water transmission characteristics of the restricting soil layers (Keene silt loam) in the experimental plots must play an important role in directing the path of infiltrating water. Past research has indicated that temporary zones of saturation are present in the soil layers during a storm. Saturated hydraulic conductivity measurements are needed to define rates and quantities of subsurface storm flow. The double tube permeameter as developed by Bouwer (SSSA, 1961, pp. 334-339) was used in an attempt to establish saturated conductivity, "K", for both vertical and horizontal directions. Unsaturated conductivities may be obtained by other methods not yet accomplished at Coshocton.

An isotropic soil should have essentially the same "K" in the vertical and horizontal directions. Anisotropy, a property of the media, is typical of the Coshocton area soils. To minimize this effect the topsoils and subsoils were evaluated by soil horizon layers. The values of vertical hydraulic conductivity (none obtained for the horizontal due to instrument difficulties) for the subsoil were assumed to be zero since about an 8 foot head of water in the double tube apparatus did not cause water to move into the soil after the initial "saturation" period of a few hours. At least eight different sites around the periphery of a plot produced the same result. This observation did not match the field sprinkling results in which the subsoil showed positive pressures during a sprinkler-rainfall event. Soil water pressures, as measured in deep tensiometers, indicated water gradients from the surface and positive pressures within the subsoil. Furthermore, water levels in fractured rock below the subsoil rose. Soil moisture measurements indicated a content less than saturation.

Contribution to ground water from the sprinkler runs, was observed at nine wells. The wells are 2 7/8-inch diameter holes with a 2-inch perforated steel pipe, gravel packed in the aquifer zone. The upper zone is clay packed between the casing and the drill hole walls. It is unlikely that surface water might follow down along the well pipe and cause a rise in water level--as only one well was located in the sprinkled area. Observation of recharge in the wells showed water levels rising several hours after start of sprinkling.

The volume of water stored in the fracture system of the coal and shale was low as evidenced from pumping tests. Pumpage rates of 0.10 gal/min. were sufficient to dewater the saturated zone near the pumped well. Further, water poured into the well casings showed a slow adjustment to normal levels.

The water movement from the plots within the rock strata appeared to be in a roughly elliptical shape in a single fracture system trending nearly parallel with the topographic contours. A single large fracture was encountered in this recharge zone and bore on a direction with the line of wells which responded to recharge from sprinkling.

The direction of ground-water movement resulting from recharge in the plot implies that very local field slopes will recharge nearby areas and bear little or no relationship to the recharge area of shallow ground-water bodies. The fracture system encountered follows the major joint pattern existing in the rock strata of Coshocton. This rock fracture system is apparently in hydraulic contact with soil so that positive pressures in the soil profile are rapidly indicated in the groundwater zone.

I. COMMENTS AND INTERPRETATIONS: Tensiometer measurements have shown the pressure gradients in soil water but acceptable conductivity values have not yet been obtained so that the flux can be evaluated. Neither do observations account for all the soil water -- input, storage, and output -- even on a plot. Field instrumentation for subsurface water movement observation is in sore need of development, particularly for the mere cohesive soils. In particular, we need to investigate the reasons for the discrepancies noted between observations due to neutron probe, tensiometers, double tube apparatus, and groundwater wells.

Perhaps the neutron probe and the double tube permeameter are measuring on the basis of samples smaller then the smallest representative elementary volume (REV) of the soil. The REV might be defined as that size sample whose size, if smaller, will not react in a manner similar to the mass or total soil volume (fig. 8.1).

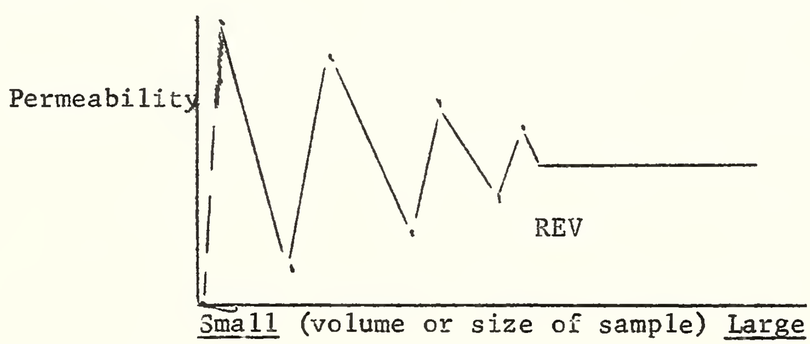


Fig. 8.1

Due to the nature of variations in root penetration, grain size, leached zones, soil cracks, etc. large variations in permeability may be expected with decreasing sample size. Perhaps the 13' x 50' plot is our Representative Elementary Volume.

J. SUMMARY: Infiltration from sprinkler runs on 13' x 50' plot with meadow cover induced interflow within the soil profile. Although the entire soil mass was not saturated subsurface stormflow discharged at the downslope trench face. Groundwater wells indicated recharge to a shallow perched water table. Variations in water head or suction and soil moisture failed to account for the total moisture flux. The hydraulic conductivity of the subsoil, as determined by the double tube permeameter, also failed to account for the transmission of percolating water to the water table. Unsolved instrumentation problems may account for some lack of resolution. The parameters used were not sufficient to establish field infiltration, interflow, and deep percolation.

A method of considering sample size in hydraulic conductivity determinations is under consideration to overcome effects of local soil heterogeneity encountered in the watershed environment.

Groundwater zones beneath interflow plots showed a promounced effect of joint orientation upon the direction of percocating waters.

A. CRIS WORK UNIT: SWC W6-cCos-4

Research outline: Interflow-streamflow relations, Ohio-9

B. LOCATION: Coshocton, Ohio

C. PERSONNEL: C. R. Amerman and J. B. Urban; cooperator-- Ohio Agricultural Research and Development Center, Wooster, Ohio

D. DATE OF INITIATION AND EXPECTED DURATION: 1961 - continuing

E. OBJECTIVES: 1. To investigate the timing with which interflow occurs.

2. To investigate the percentage of total water yield from an area that is comprised as interflow.

3. To determine methods for graphically or numerically separating the interflow component of stream hydrographs.

F. NEED FOR STUDY: To reach objective 1 and 2 of Ohio-6, it is necessary to consider all components of streamflow, how they are affected by various watershed characteristic factors and how these components combine to form a hydrograph.

G. DESIGN OF EXPERIMENT AND PROCEDURE TO BE FOLLOWED: Hydrographs of interflow, recorded on flumes which gage the flow of waters from subsurface interceptors, will be analyzed for volume, peak rate, time of peak, and along with watershed characteristics will be tested to determine how helpful each one is in devising means of separating and evaluating the interflow component of streamflow measured on complex watersheds.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Interflow watershed:

Data collection was continued on watershed 151. Due to no large storm events and lack of personnel no analysis was made.

I. COMMENTS AND INTERPRETATIONS: None

J. SUMMARY: None

A. CRIS WORK UNIT: SWC W3-cCos-1
Research Outline: A study of the areal distribution characteristics of severe local storms in northeast Ohio, OHIO-11.

B. LOCATION: Coshocton, Ohio

C. PERSONNEL: J. L. McGuinness and L. L. Harrold, cooperators; Grant Vaughan, U. S. Weather Bureau, Akron-Canton Airport, and Ohio Agricultural Research and Development Center.

D. DATE OF INITIATION AND EXPECTED DURATION: 1963-continuing.

E. OBJECTIVES: 1. To determine the depth-area relations of local severe rainstorms in northeast Ohio.

2. To determine the duration, frequency, and other characteristics of these storms and the resulting runoff and damages.

F. NEED FOR STUDY: The most damaging upland flooding occurs in the growing season as the result of local, severe rains. A dense network of gages covering a large area is required to adequately define the isohyetal pattern of these storms.

G. DESIGN OF EXPERIMENT AND PROCEDURE TO BE FOLLOWED: Over 1700 volunteer rainfall observers are functioning during the April through October season in a 1500 square mile, 4-county area north of the Station. Upon request, these observers furnish reports on local, severe storm rainfall. These reports are supplemented by radar pictures of the storm taken at the Akron-Canton Airport Weather Bureau Office and an isohyetal map is produced. These maps contain the basic data for the depth-area-duration-frequency studies as stated in the objectives.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

The Network

The number of volunteer rainfall observers has become fairly stable, there being 1687 on the rolls on December 31 compared with 1727 at the end of 1966. Response to our requests for storm information continues to be excellent. The uniform Daylight Saving Time throughout the entire network area has helped in data interpretation.

Detailed information on rainfall was collected for the storms of June 28 in northern Wayne County and July 2 in Tuscarawas County. In both cases, the center of the storm was outside the network area and further analyses were not made. Detailed information was also collected on the July 31 event which is described in detail below.

Heavy catches of rain included 2.8 inches in 45 minutes in Canaan Township, Wayne County on June 28, 3.3 inches in 24 hours on July 2 in southern Tuscarawas County, 2.2 inches in 75 minutes on July 9 in northern Stark County and 2.3 inches in 45 minutes at the same locality on July 19, 2.1 inches in 24 hours with 1.8 inches in 30 minutes in northern Wayne County on July 24, 2.6 inches in 24 hours on July 27-28 in southern Tuscarawas County, 2.1 inches in 24 hours on August 3 in southern Stark and northern Holmes Counties, 3.1 inches in 8 hours in eastern Holmes County and 2.1 inches in 2 hours in northern Stark County.

During the season, ten storms were recorded in periods of 24 hours or less in which more than two inches of rain fell. Of these, three had a recurrence interval of 100 years, two had recurrence intervals of fifty years, three had recurrence intervals of ten years, and two storms had recurrence intervals of less than five years. The recurrence intervals are the probabilities of point rainfall as computed from Weather Bureau Technical Paper No. 29.

These data point up the problem of extending point probabilities to an area. How many 100-year storms should we expect per growing season in the 1500 square mile network area? At a point in the area, we expect 0.01 of these storms, or one in 100 years, by definition. Our data indicate that the expected number of these events increases as size of area increases. The engineer concerned with sediment production from such an area needs to know something about the areal as well as the point probabilities. With enough seasons of record, our data should be helpful in at least starting on this problem.

<u>Storm of July 31, 1967</u>

An intense storm centered near the city of Massillon during the evening of July 31. Two hard bursts of rain occurred, the first from about 1930 to 2000 from an isolated convective cell and the second from 2030 to 2130 associated with the passage of a squall line. A stationary front was oriented east and west through the area at this time.

An isohyetal map for the storm is given in figure 11.1. A high reading of 3.2 inches during the 2-hour period was recorded in the core of the storm. Radar data were invaluable in defining the storm pattern in the north and east sections where gage data were somewhat scanty. A small section of the storm area close in to the radar set was not usable due to ground-clutter return masking the rainfall images.

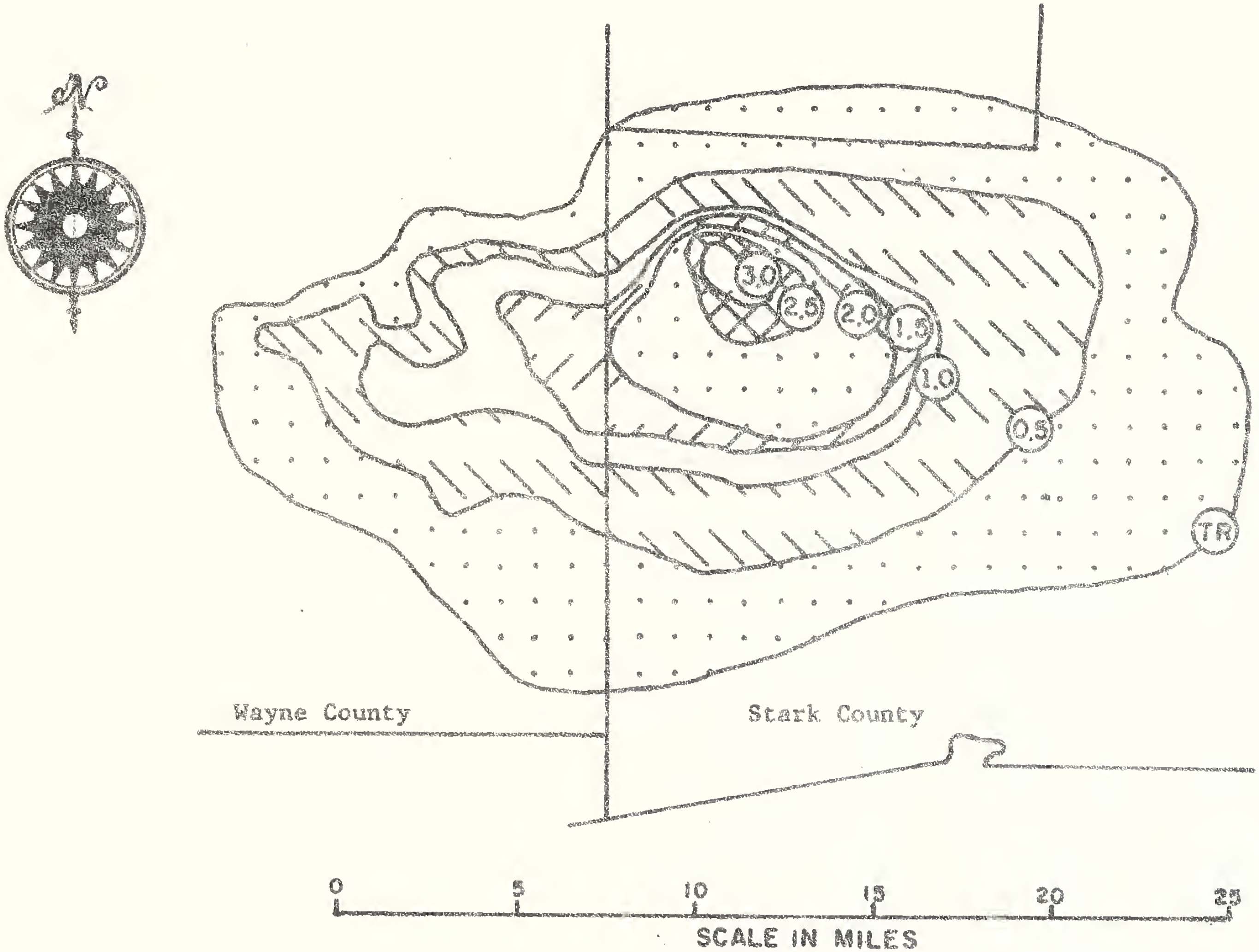


Fig.11.1--Isohyetal map of July 31, 1967 storm.

I. COMMENTS AND INTERPRETATIONS: The area-depth relationship for the storm is given in figure 11.2. The solid line is the measured curve obtained by measuring the area enclosed inside each isohyet line of figure 1 and computing the average depth of rain falling on each of these areas. The circles represent points on the relationship computed using bivariate-normal theory as suggested by Arnold Court. The fit of these theoretical points to the measured curve would seem to be quite satisfactory.

Very little damage resulted from this storm. The 30-minute break between the two rain bursts helped minimize peak runoff rates. Some street flooding occurred in Massillon but streams stayed in bank and no damage was noted in the surrounding rural areas. Considerable erosion was noted at a new housing development north of the city.

J. SUMMARY: The number of volunteers in the network has stabilized at about 1700 observers. Three storm events were investigated but only one usable isohyetal map was obtained during the year. The fit of the theoretical Gaussian relationship to the measured storm data appears to be acceptable. Within the network area of 1500 square miles, there were three storms of 100-year expected recurrence, two of 50, three of 10, and two of less than 5 years recurrence. Additional data are needed to supply an empirical answer to the question of assessing area probabilities.

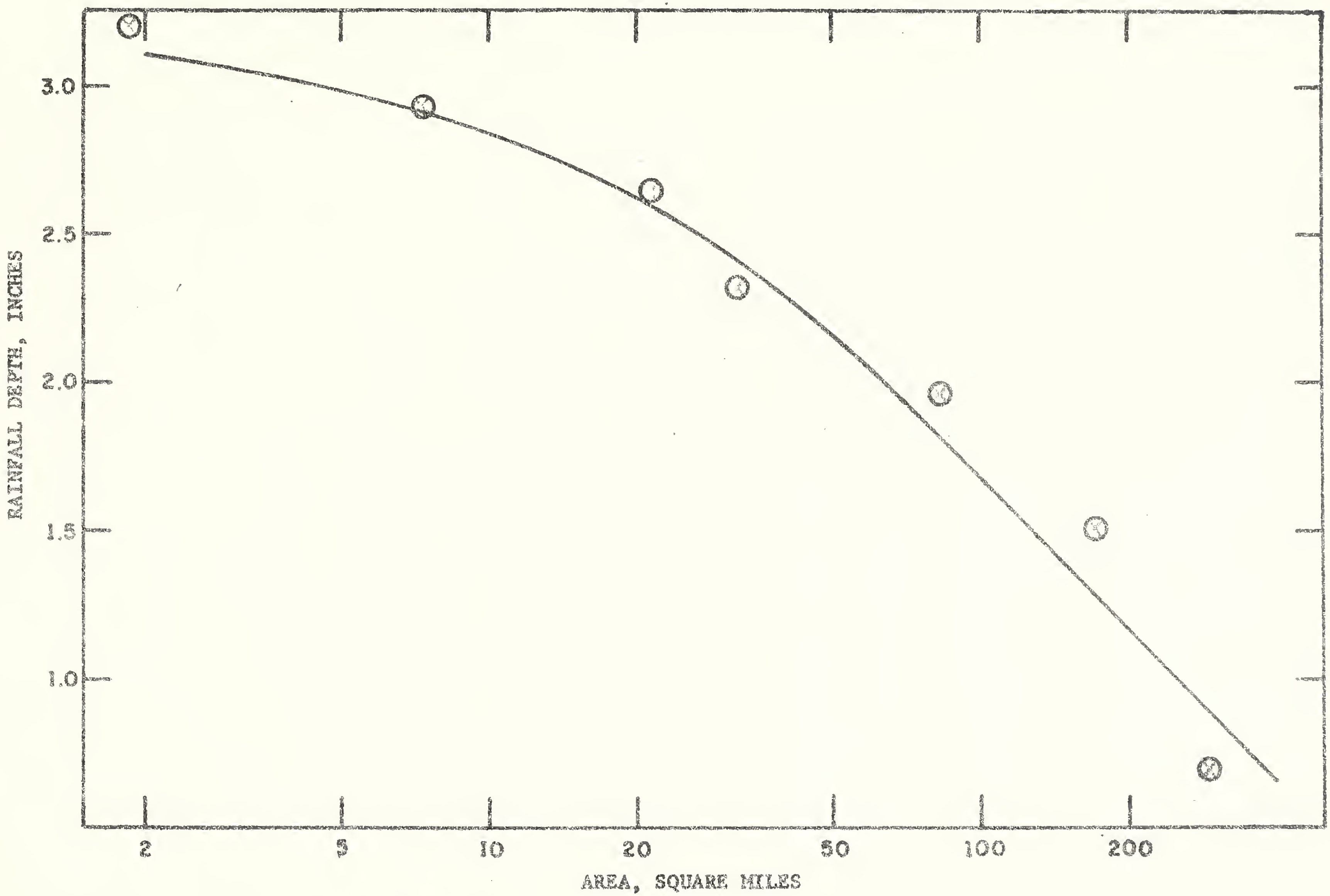


Fig. 11.2--Area-depth relations for July 31, 1967 storm; solid line as measured from map; circles from theoretical Gaussian distribution.

A. CRIS WORK UNIT: SWC W8-cCos-5

Research Outline: The relation of agricultural practices to the pollution of surface and subsurface water with chlorinated insecticides and other agricultural chemicals. Ohio-12.

B. LOCATION: Coshocton, Ohio

C. PERSONNEL: L. A. Dean, H. L. Barrows, J. E. Caro, E. P. Freeman, and R. C. Simpson, Beltsville, Md.: and W. M. Edwards, L. L. Harrold, and R. E. Youker, Coshocton, Ohio.

D. DATE OF INITIATION AND EXPECTED DURATION: 1966 - continuing.

E. OBJECTIVES: 1. To determine the rate at which nitrogen and phosphorus fertilizers and selected chlorinated insecticides are transported from agricultural lands into surface and subsurface waters.

2. To study the mechanisms by which these compounds are transported.

F. NEED FOR STUDY: Recent world wide concern over the quality of the water in streams, rivers, and lakes is leading to a critical evaluation of agricultural practices as they may affect the quality of the water that drains from the fields. Of primary importance is the movement of the persistent organic pesticides into the waterways. Reliable information is needed on the magnitude and the mechanism of the movement and factors that influence the rate.

Agricultural chemicals vary widely in the way in which they react with the soil and move across and within it. At one extreme are those that move freely with the soil water. These are readily leached into the ground water and the streams that drain the area. At the other extreme are those chemicals that are bound tenaciously to the soil colloids. Very little leaching of these compounds occurs, but they may still be removed from the area by erosion and be transported downstream with the eroded soil material.

G. DESIGN OF EXPERIMENT AND PROCEDURE TO BE FOLLOWED: An experiment was initiated in the spring of 1966 on instrumented runoff watersheds established at Coshocton, Ohio, to supply answers for these and other questions regarding the relation of agriculture to water quality. The experiment is designed to study the movement of dieldrin, nitrates, and phosphates downward through the soil profile and laterally across the sloping surface of the hill, as well as losses resulting from erosion and runoff.

Watersheds are selected for study and soil samples collected. Each area is divided into quarters according to elevation and each quarter sampled separately. Soil samples are collected at 0-3, 3-7, and 7-10 inch depths. Samples are collected prior to treatment application, immediately after treatment application, and again at the end of each growing season thereafter. These samples are frozen until analyzed.

Samples of surface water and eroded solids are collected at 3-minute intervals and multiples thereof during each storm in which significant runoff occurs. Solids are separated from the liquid and both fractions retained for analysis. The solids are frozen and the liquid refrigerated until analyzed.

Plant samples from the experimental areas are analyzed at the end of the growing season to determine the chemical loss removed by harvest. Mature corn plants are sectioned (stalks, leaves, ears) and the content of pesticide and other farm chemicals noted. Wheat plants (stems plus leaves, grain) and meadow crops by species (not sectioned) are also analyzed to determine quantities removed as wheat, straw, and hay.

Precipitation samples are taken after each storm, refrigerated and combined into one sample per month.

Selected streams in the watershed are sampled at predetermined intervals. These samples are refrigerated until analyzed.

All samples are sent to Beltsville for chemical analysis. Samples are analyzed for the chlorinated pesticides under investigation as well as their degradation products. They are also analyzed for their nitrate, chloride, potassium, ammonium and phosphate contents.

Data resulting from laboratory analysis of the samples are related to the runoff and erosion rates to evaluate quantities of pollutents. A backlog of 25 years of hydrologic data is used to relate these findings to climatic factors and normalcy.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Runoff from small watersheds.

Table 12.1 shows a summary analysis of runoff water collected from small experimental watersheds during the spring and summer, 1966 at Coshocton, Ohio.

I. COMMENTS AND INTERPRETATIONS: Early 1967 runoff was automatically sampled at two small watersheds (WS 128, dieldrin treated; WS 192, check) that had been monitored in 1966 when they were cropped in corn. The winter wheat cover on these watersheds

Table 12.1.-Analysis of runoff water from watersheds at Coshocton, Ohio, spring and summer 1967.

Location and Treatment	concentration range and (mean)					
	Dieldrin	K	Cl	NO_3 - N	NH - N	P
	ppb	ppm				
WS 128: 1966 treatment-dieldrin, N,P,K	0.8 - 4.1 (1.9)	2.8 - 11.6 (7.3)	0.3 - 19.6 (12.1)	<0.2 - 18.4 (8.9)	<0.2 - 0.6 (0.3)	<0.05 - 0.28 (0.15)
WS 192: 1966 check	0.0 - 0.4 (0.09)	1.4 - 5.8 (3.4)	0.2 - 8.6 (3.2)	<0.2 - 6.8 (2.7)	0.2 - 1.0 (0.4)	<0.05 - 0.21 (0.06)
WS 111: 1967 treatment-dieldrin, N,P,K	2.0 - 7.8 (4.2)	3.8 - 4.9 (4.3)	0.3 - 2.5 (0.7)	1.0 - 3.2 (1.5)	0.4 - 1.4 (1.0)	0.05 - 0.09 (0.06)
WS 118: 1967 treatment-dieldrin	9.6 - 17.4 (13.4)	1.3 - 2.6 (2.0)	0.2 - 2.0 (0.5)	0.4 - 5.4 (2.4)	0.3 - 1.5 (0.8)	<0.05 - 0.12 (<0.05)
WS 113: 1967 check; K	0.03 - 0.17 (0.09)	4.0 - 7.9 (5.4)	0.4 - 10.6 (3.3)	0.7 - 4.3 (2.1)	0.4 - 1.0 (0.7)	<0.05 - 0.05 (<0.05)

afforded little canopy retention and runoff from seven events was sampled in March alone. As a result of wheat development and the accompanying increase in surface cover during the spring months, only three storms after April 1 produced runoff significant for sampling.

In May, three more corn watersheds, described in table 12.2 were instrumented with automatic samplers. Nine storms

Table 12.2.-Watersheds added to the Coshocton pollution study in 1967.

WS	Acres	Practice	Treatment
111	1.18	Improved	200 units/A of N,P,K plowed down 5 lb/A of dieldrin mixed to 3 inches
113	1.45	Improved	200 units/A of K plowed down 180 lb./A of 5-20-20 banded with corn
118	1.96	Prevailing	50 lb/A of 5-20-20 banded with corn 5 lb/A of dieldrin mixed to 3 inches

occurring in June, July, September, November, and December caused runoff which was collected at one or more of these stations.

As compared to long-time averages, runoff peaks and volumes during 1967 were very low. However, over 200 runoff samples were collected from the five watersheds and analyzed for dieldrin and inorganic fertilizer elements.

Dieldrin content in the runoff water from the plot treated in the spring of 1966 (WS 123) averaged 20 times as much as that from its comparable check plot (WS 192). The concentration of fertilizer elements was two to four times greater in the water from the high fertility watershed.

There was a higher concentration of dieldrin in the runoff water from the plots treated in 1967 (WS 111, 118) than from the plot treated in the previous year. However, the same concentration (0.09 ppb) was found in the runoff water from the check watersheds of each year.

In figure 12.1 the concentrations of dieldrin, K, Cl, NO_3, and NH_4 are related to rainfall and the runoff rate hydrograph of WS 118 for the storm of July 19, 1967. The data points are concentrations of the various elements as determined by analysis of the individual automatically collected samples.

Table 12.3 is an example of the calculations needed to relate the rate and total amount of a chemical element removed in

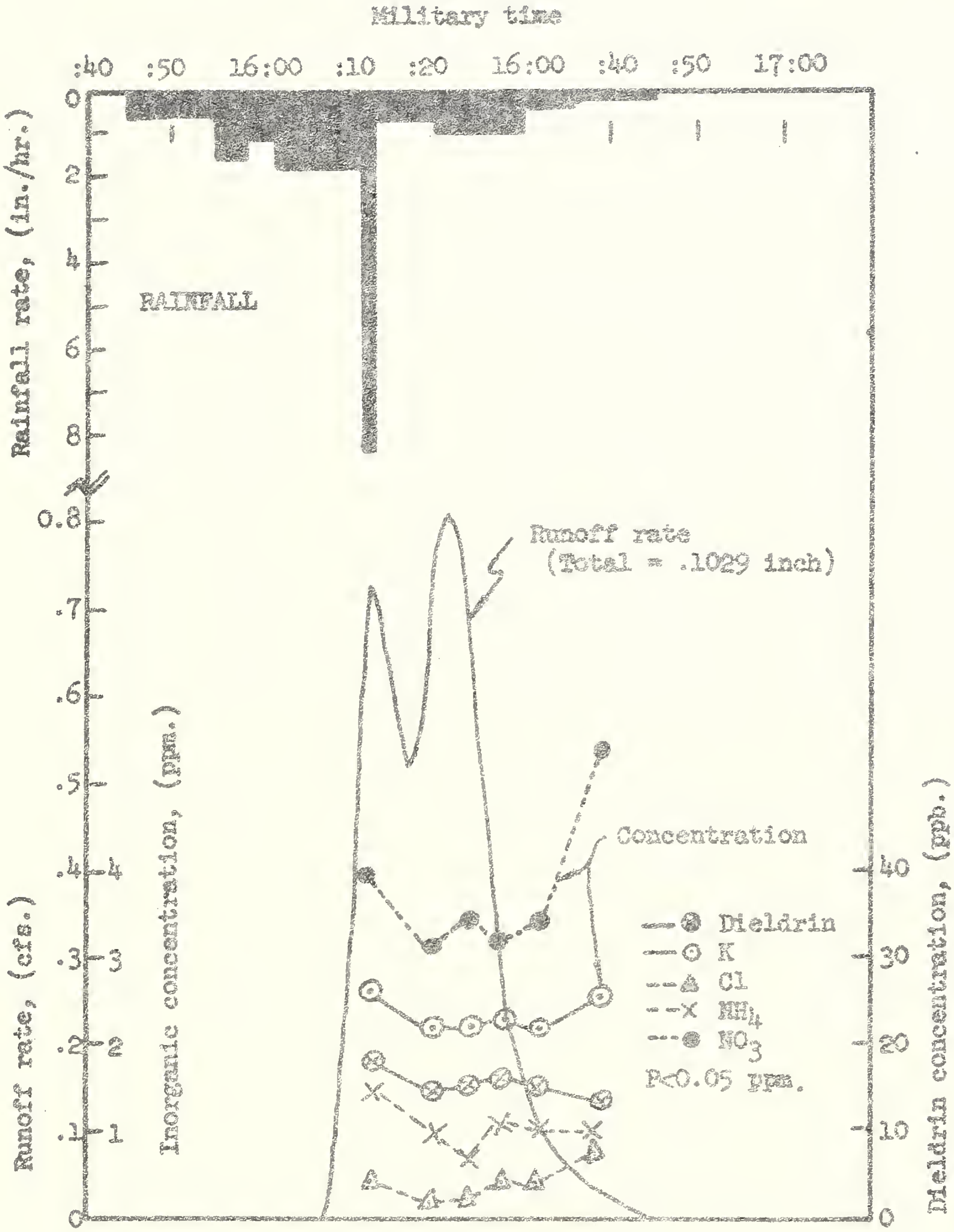


Figure 12.1 -- Rainfall, runoff and concentration of K, Cl, NO_3, NH_4, and dieldrin in runoff water from watershed 118, July 19, 1967

Table - 12.3 NUTRIENT TRANSPORT IN LIQUIDS
Watershed No. 118
July 19, 1967

Date	Time	Gage height	Discharge	K Concentration	K Transport Rate	K Transport Amount Interval	K Transport Amount Accum.
		ft.	c.f.s.	ppm	gm/min.	gm	gm
7-19-67	1557	0	0	-	0	0	0
	1600	.02	.002	(2.6)	.009	.014	.014
	1605	.02	.002	(2.6)	.009	.045	.059
	1608	.04	.007	(2.6)	.031	.060	.119
	1609	.18	.094	(2.6)	.416	.224	.343
	1610	.30	.235	(2.6)	1.040	.728	1.071
	1611	.42	.442	(2.6)	1.956	1.498	2.569
	1612	.50	.621	(2.6)	2.749	2.352	4.921
	1613	.54	.723	2.6	3.200	2.974	7.895
	1615	.50	.621	(2.5)	2.643	5.843	13.738
	1617	.46	.527	(2.4)	2.153	4.796	18.534
	1618	.46	.527	(2.3)	1.684	1.918	20.452
	1620	.52	.671	2.2	2.514	4.198	24.650
	1621	.57	.865	(2.2)	3.240	2.877	27.527
	1623	.56	.777	(2.2)	2.911	6.151	33.678
	1624	.52	.671	2.2	2.514	2.712	36.390
	1625	.48	.578	(2.2)	2.165	2.340	38.730
	1626	.42	.442	(2.2)	1.656	1.910	40.640
	1627	.38	.365	(2.3)	1.429	1.542	42.182
	1628	.32	.264	2.3	1.034	1.232	43.414
	1630	.26	.151	(2.3)	.591	1.625	45.039
	1632	.20	.113	2.3	.443	1.034	46.073
	1635	.14	.061	(2.4)	.249	1.038	47.111
	1639	.09	.029	2.6	.128	.754	47.865
	1640	.08	.023	(2.6)	.102	.115	47.980
	1645	.04	.007	(2.6)	.031	.332	48.312
	1650	.01	.001	(2.6)	.004	.088	48.400
	1700	0	0	(2.6)	0	.020	48.420

Total runoff = 0.1029 inch
= 20,775,324 gm

Average K = 2.33 ppm

Note: Concentration values in ( ) are straight-line interpolations between observed values and constant values before the first and after the last observed values.

the runoff water to the watershed hydrograph. Linear interpolations were made between measured values, and the concentrations within each short segment were converted to grams and total removed. Similar analyses have been made for other chemical elements, other watersheds, and other storms; but consistent cause and effect relations explaining concentrations found have not yet been noted. It is of interest however to note the marked increase in concentration of NO_3 at the end of the storm. Increase in concentration of K is of lesser magnitude. Other graphs showed the same trend. Runoff rates at this time were low. The flow was not diluted by rainfall at this time.

J. SUMMARY: Average dieldrin concentration in runoff water from the 1967 treated watersheds was less than 10 ppb with one sample containing 17 ppb. Dieldrin in runoff water from the 1966 treated watershed averaged 1.9 ppb while 0.09 ppb was found in that from the check plot. There was a higher concentration of dieldrin in the water from the 1967 treated plots than in that from the watershed treated in 1966. Both check plots yielded runoff averaging 0.09 ppb. dieldrin.

Concentration of inorganic fertilizer elements from the 1966 treated plot was two to four times higher than from the comparable check watershed; however, this difference was not apparent between the 1967 treated and check watersheds. Maximum phosphorus concentration in runoff was 0.12 ppm on the 1967 treated watershed and 0.05 ppm on the untreated. Maximum concentration in the runoff from watersheds treated in 1966 reached 0.28 ppm - - over twice as much.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Dieldrin persistence in soils.

Dieldrin content in the soil of watersheds treated in 1966 and 1967 is given in table 12.4.

In all cases application was at the rate of 5 pounds of dieldrin per acre mixed within the upper 3 inches of the prepared corn seedbed. Each watershed was subdivided into from five to eight sampling areas and within each area, a separate sample was compounded from 12 sub-samples for each of the 0-to 3-, 3-to 7-, and 7-to 10-inch intervals.

I. COMMENTS AND INTERPRETATIONS: The concentration of dieldrin remaining in the 0-to 3-inch soil of watershed 128 treated in the spring of 1966 has gradually decreased from a maximum of 13.9 ppm to 6.6 and from an average of 7.0 to 4.1 ppm. There has been no increase in concentration with depth and there is no evidence to indicate lateral or downslope

Table 12.4.-Dieldrin content of soils from treated watersheds at Coshocton, Ohio.

Water-shed	Sampling time	Range of Dieldrin content and (Mean) 0-3" depth	3-7" depth	7-10" depth
128	May 1966, pre-corn planting1/	3.4 - 13.9 (7.0)	0.4 - 6.8 (1.9)	0.0 - 1.0 (0.2)
128	Sept. 1966, post-corn harvest	1.8 - 11.8 (5.2)	0.1 - 3.0 (0.7)	0.0 - 0.09 (0.02)
128	Sept. 1967, post-wheat harvest	2.1 - 6.6 (4.1)	0.02 - 0.73 (0.14)	0.0 - 0.12 (0.04)
111	May 1967, pre-corn planting1/	0.1 - 2.1 (1.1)	0.1 - 0.3 (0.2)	0.0 - 0.4 (0.2)
111	Sept. 1967, post-corn harvest	1.9 - 4.2 (3.2)	0.0 - 0.2 (0.1)	0.0 - 0.1 (0.03)
118	May 1967, pre-corn planting1/	0.7 - 1.3 (0.9)	0.0 - 0.4 (0.2)	0.0 - 0.1 (0.03)
118	Sept. 1967, post-corn harvest	2.4 - 9.2 (5.4)	0.02 - 0.45 (0.2)	0.0 - 0.1 (0.03)

1/ Soils sampled one day after dieldrin application.

accumulations of the pesticide. Of the dieldrin in the 10 inches of soil after application in 1966, there remained only 44% by September 1967. Only a very small percent of the total loss can be accounted for by runoff, erosion, and crop uptake. Possible sources of unmeasured loss of the chemical are vaporization, degradation, and wind-borne dust.

Soil analysis of the plots treated in 1967 yielded puzzling results. On the basis of 5 pounds per acre of dieldrin mixed into the top 3 inches, it was expected that the upper level would have an initial concentration of about 5 ppm. In both watersheds, soil samples taken one day after dieldrin application showed a concentration only 20% of that expected. After corn harvest, however, soil dieldrin concentrations returned to expected levels. No logical explanation of the discrepancy can be offered at this time.

J. SUMMARY: Sixteen months after application, 40% of the dieldrin was lost from the top 3 inches of soil in the original treated watershed. The loss is believed to be an accumulative effect of degradation, vaporization, air-borne dust dissipation, runoff and erosion, and crop uptake. There has been no indication of pesticide movement to greater depths, in the 16-month period following treatment.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Dieldrin content of crops.

Dieldrin content of crops grown in the 1966 treated watershed 128 is shown in table 12.5.

12.5.-Dieldrin content of corn and wheat plants grown on treated watershed No. 128, Coshocton, Ohio

Plant	Planting date	Harvest date	Plant part	Range and (Mean) of dieldrin content
				ppm dry basis
Corn	5/20/66	10/9/66	Leaves	0.58 - 0.88 (0.73)
			Stalks	0.05 - 0.20 (0.10)
			Cobs	0.005 - 0.010 (0.008)
			Kernels	0.02 - 0.03 (0.022)
Wheat (immature)	10/12/66	4/27/67	Whole plant	0.39 - 0.78 (0.56)
Wheat (mature)	10/12/66	7/18/67	Stems	0.13 - 0.98 (0.51)
			Chaff	0.05 - 0.12 (0.09)
			Grain	0.005 - 0.018 (0.009)

I. COMMENTS AND INTERPRETATIONS: Analysis of corn and wheat plants grown in WS 128 show that very little of the pesticide was picked up and translocated through the plants. High dieldrin contents on corn leaves (0.73 ppm) and wheat stems (0.51 ppm) at harvest was later traced to air-borne contamination from the soil surface. However, the total removal of dieldrin by the 101 bu/acre corn crop was only 2 grams of the 6000 grams applied.

A similar trend was noted in the wheat grown in the following winter and spring.

Analyses of the 1967 corn crop have not been completed.

J. SUMMARY: Analysis of corn and wheat grown in a dieldrin treated watershed indicated a high concentration of pesticide in the leaves of these plants. A subsequent greenhouse study at the Beltsville station in which the aerial portion of the corn plants was shielded from the dieldrin treated soil showed that the high concentration found in the leaf analysis is due to surface contamination.

With surface contamination included, only 0.03% of the soil-applied dieldrin was removed by the field grown corn crop.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Pollution in streamflow and rainfall.

Peak flow samples were taken at the gage site of three larger watersheds as described below.

WS 172 44 acres, woods.

WS 177 76 acres, rotation cropped fields, pasture, farmstead and feedlot, generally medium fertilizer rates.

WS 196 303 acres, rotation cropped fields, pasture, woods, dieldrin treated watersheds 128 and 118, generally low fertilizer rates. Analysis of water samples at these sites (table 12.6) gave a measure of the pollution of water running off the surface of different land use patterns. The stream flow samples were hand taken to coincide with samples taken by the automatic equipment at the small treated watersheds. Rain gage samples collected after each rain and combined into monthly samples for each gage were analyzed to determine if there was measurable pollution in rainfall.

I. COMMENTS AND INTERPRETATIONS: There was a low concentration of dieldrin in all streams sampled. Even watershed 172, the completely wooded watershed that was considered to be uncontaminated, had a measurable dieldrin content in all samples tested - - up to 0.04 ppb. Although maximum dieldrin concentration of 0.11 ppb

Table 12.6.-Stream flow analysis, Coshocton, Ohio, spring and summer, 1967.

Pollutant	Concentration range and (mean)		
	Watershed 172 wooded	Watershed 177 below feed lot	Watershed 196 below dieldrin treatment
Dieldrin, ppb.	0.01 - 0.04 (0.03)	0.01 - 0.11 (0.03)	0.00 - 0.06 (0.01)
K, ppm	1.0 - 3.8 (2.0)	2.8 - 86.4 (15.0)	1.8 - 3.6 (2.5)
Cl, ppm	0.3 - 8.7 (2.4)	3.3 - 86.4 (14.1)	2.5 - 13.8 (7.2)
Organic N, ppm	0.1 - 0.5 (0.3)	0.3 - 4.4 (1.5)	0.1 - 1.9 (0.5)
NO_3-N, ppm	<0.2 - 0.5 (0.2)	0.1 - 14.4 (1.9)	<0.2 - 1.4 (0.5)
NH_4-N, ppm	<0.2 - 0.8 (0.4)	<0.5 - 3.2 (0.7)	<0.2 - 0.6 (0.3)
P, ppm	- - - (<0.05)	<0.05 - 1.3 (0.22)	<0.05 - 0.05 (<0.05)

was greater in the stream flowing from cropped watershed 177 below feedlot, the average was no greater than that from the basically "pure" watershed 172 in woods. Dieldrin concentration in flow from cropped watershed 196, parts of which received dieldrin, was the least of all - - 0.01 ppb.

The feedlot in watershed 177 apparently contributes significantly to pollution by fertilizer elements, K, Cl, Org. N, NO_3, NH_4, and P.

It is of interest to note that P content -- a large factor in eutrofication -- in the flow of 177 reached a maximum of 1.3 ppm. This would be mostly in surface runoff from the feedlot. As there is very little ground water flow into the stream above this gage, there is little dilution. However, underground waters enter the stream about 100 feet downstream from the gage which should reduce the concentration of this pollutent. Samples will be taken at this lower site to evaluate the effect of this dilution.

An automatic sampling system, similar to those in operation at the small watersheds, is being installed at a new sampling site directly below the feedlot to facilitate a more detailed sampling schedule than is presently possible.

Except for a few unexplained samples, water from raingages was dieldrin free.

J. <u>SUMMARY</u>: Dieldrin concentration in all three streams averaged 0.03 ppm or less. It was least (0.01 ppm) in the stream draining the basin where small fields received applications of 5 lb./acre. In the latter case, large quantities of underground water fed into the stream and weakened the dieldrin concentration.

Highest concentrations of phosphorous in stream flow -- up to 1.3 ppm, with an average of 0.22 ppm were found at 177 where surface waters come from a small feedlot and where there is little dilution by flow from underground sources. Where there is sizable underground flow into the stream -- above 196 -- P concentrations averaged less than 0.05 ppm. with a maximum value of only 0.05 ppm.

These results are for years of below-average storm runoff. Different findings may result in seasons of normal and above-normal storm experience.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Pollution study on lysimeters.

An investigation of the persistence and contribution to runoff and ground water of certain surface applied herbicides, insecticides, and fertilizer elements was started on two of the Coshocton lysimeters.

On March 30, 1967, the following treatment was applied to the meadow surface of lysimeter Y101B, of untreated poverty grass on a 13-percent slope.

200 units per acre of N as ammonium nitrate
200 units per acre of P as triple superphosphate
200 units per acre of K as muriate of potash
5 lbs. per acre of methoxychlor
20 lbs. per acre of 2, 4, 5-T (amine form)

The fertilizer elements were mixed dry in a bucket and spread by hand. The methoxychlor and 2, 4, 5-T were mixed with a gallon of water and sprinkled evenly over the surface through a garden sprinkler.

Y101A, a comparable lysimeter, was used as a check and received no treatment.

Analyses of surface runoff from Y101A and Y101B are shown in table 12.7.

I. COMMENTS AND INTERPRETATIONS:

The high concentrations of 2, 4, 5-T and methoxychlor were noted in runoff water soon after application and dropped sharply with successive storms. Only 0.05% of the 2, 4, 5-T applied showed up in runoff water and it is presumed that much of the remainder has been leached to lower depths - - or has been degraded.

Whether or not these chemicals will be detected in subsequent percolation samples, remains to be seen.

Dieldrin content in the runoff from both lysimeters was the same as in the runoff from watersheds that received no dieldrin treatment (WS 192, 113).

Percolation gradually decreased throughout the summer, quitting in mid August. During this time the concentration of Cl^- ions was monitored to indicate when the other soluble elements could be expected in the percolate. At no time was any Cl^- concentration noted.

Table 12.7.-Analysis of runoff waters from lysimeters Y101B (treated)[1/] and Y101A (untreated), Coshocton, Ohio, spring and summer, 1967.

Pollutant	Concentration range and (mean)	
	Lysimeter Y101A	Lysimeter Y101B
Dieldrin, ppb	0.00 - 0.28 (0.08)	0.00 - 0.32 (0.09)
Methoxychlor, ppb	- -- - -- (0.0)	0.05 - 8.78 (2.59)
2,4,5-T,ppb	0.00 - 0.60 (0.08)	0.1 - 491.4 (139.9)
K, ppm	2.0 - 24.8 (9.2)	3.8 - 18.2 (9.0)
Cl, ppm	0.2 - 6.9 (2.5)	0.8 - 9.0 (4.8)
NO_3-N, ppm	<0.2 - 14.8 (5.2)	0.4 - 12.0 (5.1)
NH_4-N, ppm	0.9 - 28.6 (9.4)	2.5 - 34.0 (12.0)
P, ppm	0.05 - 1.82 (0.59)	0.26 - 1.55 (0.70)

[1/] treatment; 200 lb./A each of N, P, K;
5 lb./A methoxychlor;
20 lb./A 2,4,5-T (amine).

J. SUMMARY: Initial runoff from a lysimeter treated with methoxychlor and 2,4,5-T contained high concentrations of the latter but the total removal of 2,4,5-T by runoff during the four month period following application was only 0.05% of the total applied. Percolation water in the year was insufficient to cause leaching of pollutants to underground water supply.

H. EXPERIMENTAL DATA AND OBSERVATIONS:

Improvements in automatic sampling equipment.

An improved sensing switch to instigate sampling and an event marker to accurately define the time and gage height of each sample were developed.

I. COMMENTS AND INTERPRETATIONS: As described in the 1966 annual report and in ARS-41-136, "Automatic sampling technique to determine extent of pollution in runoff from agricultural watersheds", the automatic sampler is activated by a pressure switch hanging in the stilling well. As the runoff level rises, air trapped under a bell-shaped housing flexes a diaphram which operates a small, sensitive switch. During the year, this switch presented problems several times as described below.

1. To be sensitive to the gradual pressure change caused by rising and falling water levels, the switch, itself, had to be made of very light-weight material. This material could not withstand repeated current surges produced upon operations; and as a result, it burned out.

2. This type of switch was supported by its heavily insulated current carrying wires. Slight bends and twists in the plastic insulation responded to temperature changes and affected the level of the hanging switch.

3. There was a varying (not consistent) lag between levels at which the switch opened and closed. If the switch was positioned to close at a stage of 0.10 foot, it might not open again until the water level dropped to 0.03 $\pm$ 0.02 feet.

A new switch mechanism was designed that is expected to operate more satisfactorily. The contact points are heavy - not apt to burn out, the activation level is maintained over a wide temperature range, and the on-off lag is consistent and less than 0.02 foot.

A mercury switch, supported on a pivot point near one end, tips as the float rises and the electrical contact is made. When the water level falls again, the counter weight rises, bringing with it the contact end of the switch which tips the mercury away from the contact points.

Another improvement in the automatic sampling system was the addition of a time-of-sample indicator which defines exactly the time and, therefore, the gage height of each pumped sample.

Prior to the addition of this event marker, the sampling time for each jug was calculated by adding the pre-set time interval between samples to the time at which the first sample was taken Since the time that the first sample was taken could not be determined accurately, and since the sampling interval could be slightly longer or shorter than desired; the exact time and gage height of succeeding samples, especially the last few, could not be determined. Fortunately, the flow rates changed very little at this period.

The event marker consists of an extra pen which makes a single over-riding trace near the bottom of the normal water stage recorder chart. The pen is mounted on the end of an electro-magnetic coil which in turn is mounted on the base of the recorder. The coil receives 115 volt AC signal each time the normally open valve in the return line of the sampling system is activated. The current flowing through the coil magnetizes the soft iron core and pulls the pen arm down, causing a blip in the over-riding pen trace.

This blip is repeated each time the normally open valve closes, which coincides with the pumping of a sample. The resulting hydrograph shows the normal gage height as a function of time as well as a series of blips indicating when each sample was taken.

J. <u>SUMMARY</u>: A sensing switch for the automatic sampler which is activated by a rising float has been developed to replace the inferior pressure-operated switch used previously.

An auxillary pen has been designed to indicate time and, therefore, gage height for each pumped sample.

SUMMATION OF IMPORTANT FINDINGS

SWC W3-cCos-1: Within a 1500 square mile network of rain gages, volunteer observers reported point rainfall amounts that showed three storms of 100-year expected recurrence, two of 50, three of 10, and two of less than 5 years -- all in the summer of 1967. These point rainfall recurrence probabilities are based on USWB data. These research network observations will shed light on the problem of assessing rainfall probabilities on an areal basis. Designs of sediment pools and hydraulic structure features of reservoirs will be affected by these findings.

Local severe storms in a 1500 square mile observation network cover areas of 20 to 200 square miles, as shown by isohyetal maps of three summer storms in the period 1963-67. Other severe storms occurred in this 5-year period; all but three extended outside the observation network. The storm of June 5, 1963 had the greatest rainfall at its center, 4.8 inches, and an average depth of 2.6 inches over an area of 20 square miles. No data were available to determine the depths beyond this size. The next highest storm falling within the gage network area, July 31, 1967, had a maximum depth of 3.2 inches, an average depth of 2.6 inches over 20 square miles, and 1.1 inches depth on area of 200 square miles.

These findings show a striking deviation from values developed from USWB network data. For example, their 100-year average depth for a 20 square mile area is 1.9 inches whereas the values for three storms in 5 years of observations were 3.4, 2.6, and 1.1 inches. There were more than 25 other storms in this part of Ohio but no area study could be made because significant parts of the storms fell outside the gage network.

Of nine different site characteristics measured at 23 rain gage locations, exposure and aspect were best related to rain catch. However, not much of the variance of rainfall was explained by these two factors or by elevation, slope, position, shelter, ridge direction and distance, or rise. The study was made of 2 years of observations on a 30-acre rolling pasture area.

SWC W3-cCos-2: Watershed studies of cultural practices on cornland on well drained soil showed that mulch cover on no-tillage, continuous corn maintained moisture levels in the 7-inch plow layer at no less than 24% by volume, whereas that in conventional corn in 4-year rotation depleted to a low point of 12%. Evaporation suppression on the former prevented the development of a large moisture holding deficit in the topsoil. Much of the subsequent storm rainfall retention passed through this profile section on down to the 30-inch depth. Moisture increase in conventional tillage having a larger moisture-holding deficit appeared to a depth of only 15 inches. Under these conditions, recharge to ground water should occur earlier and by greater amounts under no-tillage corn than in conventional tillage.

A technique for predicting soil moisture in the 0- to 7-inch depth under meadow developed from previous years of soil moisture observations was tested against 9 additional watershed-years of measured data. Correlation between predicted and measured water contents for 120 observations was 0.94 with a standard deviation of 0.20 inch.

Plowing an alfalfa timothy sod to a depth of 16 inches in 1964 in a field normally plowed 7 to 8 inches deep caused the volume weight in the 13- to 16-inch depth to decrease about 25%. This loosening remained for 3 years (corn, wheat, and 1st-year meadow). In the 4th year (2nd-year meadow), there was some consolidation, but the volume weight is still 15% less than normal. This loosening is expected to provide greater storm water retention potential and consequently less storm runoff.

Interflow on a 13 ft. x 50 ft. sprinkler plot was observed as discharge in the downhill trench although the soil mass above was not saturated. Ground water wells at this time showed significant recharge. Hydraulic conductivity of the subsoil as determined by the Bouwer double tube permeameter along with variations in water potentials failed to account for the total moisture flux.

SWC W4-cCos-3: Percolation to ground water beneath a sprinkled interflow study plot formed a water mound. Ground water dispersed from the downslope end of the plot in a roughly elliptical shape with the major axis of the mound normal to the plot land slope. This coincides with the direction of the major joint system. It was apparent that the joint system has a major influence on subsurface water movement. This finding has an important bearing on defining part of the flow system in watershed studies.

SWC W4-cCos-3: continued

Initial studies of water temperatures in a drain tube, spring flow,and stream flow exhibited interesting and apparently meaningful relationships. Where aquifer storage is relatively small temperature changes in soil are reflected closely by temperature changes in spring flow and spring flow rates vary widely. Temperature changes in spring flow from aquifers of larger storativity are of lesser magnitude and there is less variability of discharge.

SWC W6-cCos-4: Relocation of a stream gage 220 feet downstream from its present site increased the drainage area 5% and increased total runoff volume for 1967 by 32%. At the new site the gage weir is based on a natural impermeable underclay whereas the base of the old gage is 15 feet in elevation above this clay bed. Monthly peak flow values were about the same at both sites suggesting that storm runoff was measured adequately by the old gage. However, some sustained flow was bypassing the old gage in the valley alluvium and fractured rock.

SWC W8-cCos-5: Studies of pollution in runoff water from agricultural watersheds showed that dieldrin (chlorinated hydrocarbon pesticide) was observed in flow from land which had received no dieldrin application at concentrations averaging 0.09 ppb. Runoff from the watershed receiving 5 lb. dieldrin per acre in 1967 contained an average of 10 ppb dieldrin and a maximum value of 17 ppb. Runoff this same year from the watershed receiving a similar dieldrin treatment in 1966 averaged only 1.9 ppb.

Maximum phosphorus concentration in runoff was 0.12 ppm on the 1967 treated watershed and 0.05 ppm on the untreated. Treatment consisted essentially of 200 lbs./acre of N, P, and K. From the 1966 treated watershed, the 1967 runoff had a maximum concentration of 0.28 ppm phosphorus, over twice that in runoff from the 1967 treated watershed. Both 1966 and 1967 were years of fairly low rainfall and runoff rates. There was very little erosion. Past records of rainfall and runoff indicate that runoff and erosion for 1966 and 1967 were well below average. Greater amounts and higher concentration of dieldrin and phosphorus may be expected in higher runoff in more nearly normal years.

Of the dieldrin mixed into the top 3 inches of soil of cornland watershed in May 1966, only 40% remained 16 months later. There was no evidence of dieldrin moving to greater depths. Loss is believed to be the accumulative effect of degradation, vaporization, air borne dust dissipation, runoff, erosion, and crop uptake. The last three have been observed to be very small, crop removal being only 0.03% of the quantity applied to the soil.

SWC W8-cCos-5: continued

Samples of runoff from a "pure" watershed of 43 acres of woodland showed average concentrations of 0.03 ppb of dieldrin and less than 0.05 ppm of phosphorus. Dieldrin concentration in stream flow from a 303-acre watershed, 1% of the area having received dieldrin, averaged 0.01 ppb. Phosphorus concentration in stream flow of a 76-acre watershed containing a beef-cattle feed lot reached a maximum of 1.3 ppm and averaged 0.22 ppm. These results are also from years of below-average storm runoff.

[illegible] continued

Samples of [illegible] from [illegible] showed [illegible] of woodland showed average concentrations of [illegible] acidity and less than [illegible] ppm of phosphate [illegible] concentration in [illegible] above [illegible] 17 of the [illegible] analyzed [illegible] ppm. Phosphorus concentrations [illegible] were associated with [illegible] a maximum of [illegible] are also from [illegible] years at below [illegible]

LIST OF PUBLICATIONS

SWC W3-cCos-1

None

SWC W3-cCos-2

Amerman, C. R. and McGuinness, J. L. 1967. Plot and small watershed runoff: Its relation to larger areas. ASAE Trans. 10:4, 464-466.

Fenzl, R. N. and Amerman, C. R. 1967. Modern theory in hydrologic analysis: A symposium. ASAE Trans. 10:3, 378.

Harrold, L. L. 1967. Measuring evapotranspiration by lysimetry. ASAE, Dec. 5-6, 1966 Conf. Proc. 28-33.

Harrold, L. L., Triplett, G. B. and Youker, R. E. 1967. Watershed tests of no-tillage corn: A progress report. Journal of Soil and Water Conservation, 22:3, 98-100.

Harrold, L. L., Triplett, G. B. and Youker, R. E. 1967. Less soil and water loss from no-tillage corn. OHIO REPORT on Research and Development, 52:2, 22-23.

Mustonen, S. E. and McGuinness, J. L. 1967. Lysimeter and watershed evapotranspiration. Water Resources Res. 3:4,989-996.

SWC W3-cCos-3

Amerman, C. R. and McGuinness, J. L. 1967. Plot and small watershed runoff: Its relation to larger areas. ASAE Trans. 10:4, 464-466.

SWC W6-cCos-4

Amerman, C. R. and McGuinness, J. L. 1967. Plot and small watershed runoff: Its relation to larger areas. ASAE Trans. 10:4, 464-466.

Fenzl, R. N. and Amerman, C. R. 1967. Modern theory in hydrologic analysis: A symposium. ASAE Trans. 10:3, 378.

SWC W6-cCos-4 (Continued)

Harrold, L. L. 1967. Possible effects of plow depth on hydrology of small basins. ASCE Conference Preprint No. 526, Oct.

Harrold, L. L. 1967. Measuring evapotranspiration by lysimetry. ASAE, Dec. 5-6, 1966 Conf. Proc. 28-33.

Mustonen, S. E. and McGuinness, J. L. 1967. Lysimeter and watershed evapotranspiration. Water Resources Res. 3:4, 989-996.

SWC W8-cCos-5

Harrold, L. L., Barrows, H. L. and Bentz, W. W. 1967. Automatic sampling techniques for pollution studies on runoff from agricultural watersheds. U.S.D.A. ARS-41-136, 12 p.

Harrold, L. L., Triplett, G. B. and Youker, R. E. 1967. Watershed tests of no-tillage corn: A progress report. Journal Soil and Water Conservation, 22:3, 98-100.

Harrold, L. L., Triplett, G. B. and Youker, R. E. 1967. Less soil and water loss from no-tillage corn. OHIO REPORT on Research and Development, 52:2, 22-23.

MISCELLANEOUS

Visitors from 10 states and 14 foreign countries came to the station. In 1967, the number of people learning of the station research program totaled 2050; of which 994 came in 24 tours and 830 were reached in 11 talks given at meetings away from the station.

January	4	J. B. Urban gave a talk to Rotary Club of West Lafayette, Ohio.
	16-17	L. L. Harrold attended the SCSA All-Ohio chapter meeting and Ohio Federation in Columbus, Ohio.
	23	Messrs. Ritter, Vaughan, Teage, Long from USWB, Akron-Canton Weater Bureau.
	29	15 Tour, from Bedford, Ohio
	31	L. L. Harrold participated in judging FFA speakers at Riverview High School.
February	1	Todd and Steve Henderson, Coshocton, Ohio.
	4 - 8	Fred Blaisdell and L. L. Harrold presented the SWC Hydraulic Laboratory research program on "Hydraulic performance of Conservation Structures" - - problems, research, application - - to six separate sessions at the meeting of the National Association of Soil & Water Conservation District in Cincinnati, Ohio.
	10	Mr. & Mrs. Del Krenik, Sec'y-Treas. Minn. SWCD. visit along with Wayne Darr, Pres. Ohio SWCD.
	14	Drs. Barrows, Dean, Carlson, SWC, Beltsville, visit.
	17	Melvin Amerman, Santa Ana, California.
March	7	Mr. Glass, Beltsville, Maryland
	13	L. L. Harrold talked to FFA boys at Riverview High School.
	21-22	England, Onstad , Jamieson, USHL Beltsville, Maryland.
	23	Merva, Chanhan, Gulati, Schwab, OSU, Columbus, Ohio.
	27-28	L. L. Harrold attended NC-66 meeting in St. Paul, Minnesota.

MISCELLANEOUS (Continued)

April	3	Tour, 20 Scouts from Fresno, Ohio.
	6	Tour 20 Vocational Agricultural students from Zanesville, Ohio.
	7	Tour, 10 Science students from Wickliff, Ohio.
	13-14	L. L. Harrold consulted with ARS-SWC and State personnel, Madison, Wisconsin, on watershed studies.
	17-20	J. L. McGuinness presented paper at AGU Meeting, Washington, D. C.
	19	Drs. Wadleigh and Rainey - SWC, Beltsville, Maryland.
	19-20	W. M. Edwards attended ARS Pesticide Meeting in Madison, Wisconsin.
	2-	Jeung Saw Ryn, Seoul, Korea and Rev. Hoy, Canal Lewisville, Ohio.
	21	Dr. Woolhiser, Ft. Collins, Colorado.
	22	Tour, 4 from Sunbury, Ohio
	24	Dr. Jones, Health Commissioner, Zanesville, Ohio.
	26	Messers. Heft, Brunny, Nolte, Ohio State University.
	28	Tour, 5 from Marion, Ohio.
	28	Schneider and Rischer, Stark County Engineers Office.
May	2	Tour, 22 Vocational Agricultural students from Fredericktown, Ohio.
	2	L. L. Harrold gave talks to two High School Science classes, Coshocton, Ohio.
	3	Tour, 21 High School class from Frazeyburg, Ohio.
	4	Donald Richter, Columbus, Ohio.
	5	Tour, 65 from West Lafayette, Ohio.
	6	Tour, 10 from Bluffton College.
	8-10	C. R. Amerman, W. M. Edwards, J. B. Urban, L. L. Harrold, visited MIT, Cambridge, Mass. to discuss problems of flow of water through porous media.

MISCELLANEOUS (Continued)

May	10	Dr. D. G. Jamieson, Beltsville, Maryland.
	11	Dr. Carl Johnson, Ohio State University, Cols. Ohio.
	11	Dr. and Mrs. G. H. Edwards, Pinkneyville, Illinois
	12	Miller and Moser, Ohio State University, Cols. Ohio.
	13	Tour, 16 from Kent State University
	17	Tour, 120 from Ohio State University
	18	Tour, 22 from Dennison University
	18	Tour, 220 from Coshocton High School.
	24	Tour, 21 4-H Club members from Coshocton, Ohio.
	25	Prof. Ricca, P. Okoye, E. Balk, Ohio State Univ.
	25	Tour, Prof. Taiganides and 7 from Ohio State Univ.
	25	Tour, Dr. Lehr and 22 from Geology Dept., Ohio State University.
	26	L. L. Harrold served on graduate committee for oral examinations for Geo. Merva, candidate for PhD, OSU, Agricultural Engineering Department.
	31	L. L. Harrold departed for 3-months USAID/Agriculture research consultant in Turkey.
June	2	Dr. C. A. Van Doren, St. Paul, D. D. Smith, Beltsville, Maryland.
	6	Moyer, Bou, Molnar, Lovely, ARS, Iowa State University.
	8	Mrs. L. C. Zeernan, South Africa, Wells, Turner, Montern, Frecate, Illinois and Ohio.
	13	Ed. Walton, St. Ann, Mo. and W. E. Meosdden, Palo Alta, California.
	19-30	J. B. Urban attended MIT short course, Groundwater Hydrology and Flow through porous media, Cambridge, Mass.
	21	Dr. Fitzpatrick, CSIRO, Canberra, Australia

MISCELLANEOUS (Continued)

June	22-23	W. M. Edwards attended Summer Meeting, N.C. Branch American Society of Agronomy, Wooster, Ohio.
	23	Prof. Ricca, E. Balk, Ohio State University.
	28	Tour, 42 from Kent State University, Kent, Ohio.
	28	Marvin Miller, ESSA, Weather Bureau, Columbus, Ohio.
	30	Tour, 7 from Utica Ohio High School.
July	13	Jack Saathoff, Dir. National Youth Corps, (N.Y.C.), Coshocton, Ohio
	13	Robert Alrutz and W. Slate, Dennison University.
	17	Drs. Taiganedes, and Hamdy, Ohio State University.
	19	Amerman, McGuinness, Urban, and Edwards to Dennison University.
	21	Tour, 200 Ohio 4-H Camp and Rev. Donald Kline, Cleveland.
	27	Tour, 11 Ohio FEI winners of Agricultural Engineers.
	6 - 30	Bradford Carwell, OSU graduate student in geology; working on thesis at station facility.
	27	Ronald Murray, Dept. Forestry, Canberra, Australia.
	28	Rev. Thenton, Huddlesford, England.
August	3	Station Staff visited PL566 SCS project at Celeryville, O. water management.
	4	Hellickson and Simmons, University of West Virginia.
	8	Mr. Soren Miranda, University of Philippines.
	11	James Dooge, Cork, Ireland, Schroeson, Jamieson, Onstad, USHL, Beltsville, Maryland.
	15	Bordne and Liggett, Professors, Kent State University
	24	Visitors from India, Uganda, Nigeria, and Kenya.
	24	R. H. Johnson, Dept. Geography, Univ. Manchester, England observed stream morphology at research station.

MISCELLANEOUS (Continued)

August	29	Dr. Halevy, International Atomic Energy Agency, Vienna, Austria.
	30	Tour, 10 Scouts, West Lafayette, Ohio
September	5	Krishnarajah, Soil Conservation Officer, Ceylon.
	18	Ferrell, Columbia Gas System, Charleston, W. Va.
	19	Rawitz and Parmele, NEHRC, SWC, Univ. Park, Pa.
	20	Dr. Lippman, Colorado Springs, Colorado
October	2-6	C. R. Amerman attended Div. Conference, Berkley Springs, W. Va.
	5	Ron Whipky, USFS, Columbus, Ohio
	9	L. L. Harrold returned to Station.
	18	L. L. Harrold presented a paper, ASCE, New York City, N. Y.
	21	Tour, 20 erosion class, Ohio State University
	25	Tour, 90 conservation class, Ohio State University
	25	L. L. Harrold reported to Coshocton Kiwanis Club on participation in USAID/Agriculture program in Turkey.
November	1	L. L. Harrold reported to Rotary Club, West Lafayette, Ohio
	2	Walter Arminger, Lab. - Beltsville, Maryland
	3	Prof. Walter U. Gartska, Colorado State University
	6-10	W. M. Edwards attended annual meetings of American Society Agronomy, Washington, D. C.
	13-16	L. L. Harrold attended Branch Staff meeting at Urbana, Illinois.
	16	SCS Area meeting (45) at Station.
	17	L. L. Harrold participated in Ohio Water Resources Committee Meeting, Columbus, Ohio.

MISCELLANEOUS (Continued)

November	20	Ohio Power representatives engaged in coal strip mining visited Station and discussed research needs in strip mined areas.
	20-21	H. N. Holtan, England, Stephenson, USHL, Beltsville, Maryland.
	21	Prof. Ricca, Taiganedes, Balk, Wicks, Briggs, of Ohio State University.
	27	L. L. Harrold reported to Business and Professional Women of Coshocton, Ohio.
	27	Clarence Muntz, Civil Engineer, Ohio Highway Dept., New Philadelphia, Ohio.
December	1	W. M. Edwards and L. L. Harrold participated in Ohio Soil and Water Technical Committee, Ohio State University.
	4-5	W. M. Edwards and L. L. Harrold met in Beltsville to confer on pollution studies at Coshocton, - - progress and future.
	11-15	L. L. Harrold attended the ASAE tillage conference and Winter Meeting in Detroit and presented a paper by Piest and Spomer.
	17	L. L. Harrold reported to the Coshocton County Bar Association.
	19	L. L. Harrold reported to Coshocton Rotary Club.
	21	Actavian Berbecel, Bucharest Institute Meteorologie, Romania.